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THE SEPTEMBER SCIENTIFIC MONTHLY

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THE SCIENTIFIC MONTHLY

SEPTEMBER, 1931

SINANTHROPUS—PEKING MAN[1]

ITS DISCOVERY AND SIGNIFICANCE

By Professor G. ELLIOT SMITH

UNIVERSITY OF LONDON

In thanking the Harvey Society for the honor of being invited to give this address, I must also make open confession of the fact that I am breaking the high tradition of Harvey Lectures. For my distinguished predecessors in this office have given you in their respective lectures accounts of their own original investigations. My task on the present occasion is the humbler, though not less important one, of giving you an account of other men's investigations on the fossil remains of *Sinanthropus*, the Man of Sin (China), which I have recently been privileged to witness in Peking. In attempting to give you some idea of the impression made upon my mind during this mission of ancestor worship in China, I find it difficult, without using adjectives that seem extravagant, to express my feelings when I saw the remains of the most primitive member of the human family so far recovered. The accounts of the fossils given by Dr. Davidson Black in "Palaeontologia Sinica" and the "Bulletins of the Geological Society of China" were so strictly objective and written with admirable restraint and economy of comment that there was always at the back of my mind the possibility that the impression of the fossils and their meaning which I formed from reading these accounts might possibly have exaggerated their importance. The material, however, has proved to be even more impressive and significant than I had realized before I saw it. The Peking skull is certainly the most illuminating relic of early man. In this address I want to explain my reasons for this opinion and for regarding the work done in Peking during the last three years as marking a new epoch in the study of human palaeontology.

The only two fossils of primitive members of the human family comparable in age with *Sinanthropus* are *Pithecanthropus*, found by Dr. Eugen Dubois in the bank of the Solo River of Central Java in 1891, and *Eoanthropus*, found near the village of Piltdown in Sussex by the late Mr. Charles Dawson in 1912. Both discoveries were due to the good fortune and insight of individual discoverers. Doubt and suspicion have been cast on both fossils ever since they were found and the lively controversies concerning their age, their nature and affinities have prevented any general agreement as to their real significance. Both were deposited in gravels or tufaceous material along with remains of extinct mammals of various geological ages, and the association of particular fossils with the human remains was an open question. Writing in *Science* of February 22, 1929, Profes-

[1] Harvey Lecture delivered at the New York Academy of Medicine on December 4, 1930.

sor Henry Fairfeld Osborn discussed the difficult problems of the dates of the gravels in which the remains of *Pithecanthropus* and *Eoanthropus* were found. The Ape Man of Java was at first supposed to be Pliocene in age. Then opinion gradually changed, and most writers now assume from the evidence of the elephant-like fossils such as *Stegodon* that the gravels on the bank of the Solo River are Lower Pleistocene. Professors Dietrich, of Berlin, and Osborn, of New York, now regard the Proboscidean and other quadrupeds associated with *Pithecanthropus* as Middle Pleistocene, and the Ape Man as another instance of the survival of a very primitive type of mammal in a forest environment where food was plentiful and safety was assured by concealment or flight rather than by open competition with the use of weapons. If this opinion should be confirmed—and Mr. van Es, the geologist in charge of the survey of the Solo region, is now preparing an authoritative opinion on the question—then *Pithecanthropus* might prove to be the degenerate descendant of a more primitive weaponless form such as *Sinanthropus* seems to be.

Professor Osborn suggests the possibility that Piltdown Man may be as old as the Pliocene. He claims that the dark-colored fragments of the skull of *Eoanthropus* were intermingled with similarly colored fragments of Proboscidean molars of unquestionable Upper Pliocene age belonging to *Archidiskodon planifrons* and *Anancus arvernensis*. As other tooth fragments (which, however, are lighter in color) belonging to a Lower Pleistocene hippopotamus are also present it is possible that *Eoanthropus* also may belong to the Lower Pleistocene. In the case of *Sinanthropus* there is no such uncertainty as to the contemporary fauna, for the human remains were left on the floor of a cave and a vast number of the animals which roamed the region of Chou Kou Tien in these remote times left their bones in the same cave. As all these fossils belong to the same geological epoch, the Lower Pleistocene, there can be no doubt of the age of *Sinanthropus*.

In Dr. J. Gunnar Andersson's preliminary report on the Chinese site Chou Kou Tien (in 1923) he was inclined to interpret the presence of fossil remains of a true horse and the absence of *Hipparion* as evidence of an Upper Pliocene age. As fresh material was collected and intensively studied in 1927 and 1928, however, it became possible definitely to determine the age as Early Pleistocene, or what Professor Grabau calls "Polycene." The laborious task of developing and studying the vertebrate fossils has been carried out in large measure by Dr. Chung-Chien Young, who was trained under Professor F. Broili in the University of Munich in association with the Nestor of Chinese paleontology, Professor Max Schlosser. Père Teilhard de Chardin, in collaboration with Dr. Young, published a comprehensive survey of the evidence in the Bulletin of the Geological Society of China (1929), from which I quote a few sentences. Remains of more than fifty types of mammals, besides amphibia, reptiles and birds, were found. The most characteristic forms associated with *Sinanthropus* were the flat-antlered deer (*Euryceros*), a rhinoceros comparable to the species *sinensis*, *Hyaena sinensis*, and other interesting creatures such as a big beaver (*Trogontherium*) and the primitive buffalo (*Bubalus*). The paleontologists are agreed that the deposit is definitely older than the loess (Middle Pleistocene), which includes remains of *Rhinoceros tichorhinus*, *Hyaena crocuta*, *Cervus elaphus*, instead of the different species of the same genera at Chou Kou Tien. If the deposits in which *Sin-*

anthropus occur are thus shown to be definitely older than the Middle Pleistocene, the absence of truly archaic types, such as the big *Hipparion* and *Chalicotherium*, and the presence of modern types, such as *Equus*, indicate an age later than the Pliocene. The contents of the caves and fissures in the Ordovician limestone include breccia, gravel, sand and clay.

The question is repeatedly asked what number of years have elapsed since the end of the Pliocene period. This can not be answered with any degree of certainty. Recent researches on this problem have been clearly summarized by Dr. Chester A. Reeds in an article entitled "How Old is the Earth?" in *Natural History* (March–April 1931). Assuming the reality of Pliocene Man, Dr. Reeds suggests that the antiquity of man must be at least 1,500,000 years. Hence we may tentatively adopt the view that a million years represents the scale of time since the Man of Peking roamed the Western Hills. Although some few of the bones found in the deposits may have been introduced by flood-waters most of the bones have been left in the cave or brought in by animals which lived there in Early Pleistocene times. Père Teilhard de Chardin and Dr. Young think there is reason to believe that the *Sinanthropus* family whose remains have been recovered actually lived in the Chou Kou Tien cave.

The discoveries in China have provided evidence to link together all three genera of Early Pleistocene men into a coherent and correlated series. They also confer upon the fossils from Java and Sussex a respectability that formerly was widely denied them. Moreover, the Man of Peking is a much more generalized and primitive type than the other two genera and the examination of his remains enables us to picture what the common ancestor of all three —the as yet hypothetical Pliocene Man —was like. For these, and other reasons to be explained later, the discoveries at Chou Kou Tien have a unique interest and significance. They establish a sure foundation upon which to build our conceptions of the earlier members of the human family.

The Circumstances of the Discovery

The history of the circumstances under which the fossil remains of man have been recovered is full of interest and not without importance. The finding of the remains of *Pithecanthropus* and *Eoanthropus* was due to brilliant individual achievements. The Chinese discoveries, on the other hand, were the result of a systematic search and organized team work extending over several years, in the course of which paleontologists of different nationalities followed up slight clues and thus were led on step by step to the culmination—at any rate for the present—of the discoveries in December, 1929.

For many years the museums of Europe and America have been obtaining fossils from China by purchasing "dragons' bones" from the druggists' shops in Peking and elsewhere. Some years ago Professor Max Schlosser ("Die Fossilen Säugethiere Chinas," Abhandl. d. bayerisch. Akad. d. Wissensch. Bd. XXII, 1903), summarizing the knowledge obtained by such means, referred to a fossilized tooth sent to him by Dr. Haberer from Peking. He suggested that it might possibly be that of a very early ape-like man or an exceptionally man-like ape, who might be as old as the Earliest Pleistocene or even the Pliocene period. As, however, nothing was known of its provenance or associations, it was not possible to estimate the full significance of this remarkable observation. His keen diagnosis was enough, however, to keep the

FIG. 1.[2] THE TOOTH WHICH IS THE TYPE OF *SINANTHROPUS PEKINENSIS* (2)

COMPARED WITH THE CORRESPONDING TOOTH (1) OF A MODERN CHILD AND THAT OF A YOUNG CHIMPANZEE (3).

minds of men of imagination alert and open for further discoveries of very primitive ape-like men in the Far East.

The inauguration of the National Geological Survey of China created the circumstances that led to the great discovery, which provides such complete confirmation of the possibility adumbrated in Professor Schlosser's brilliant argument.

When Dr. V. K. Ting, the director of the survey, invited Professor J. Gunnar Andersson, formerly director of the Swedish Geological Survey, to act as adviser, China secured the services of a paleontologist with a rare flair for the discovery of promising sites.

The primary object of the institution of the survey was the strictly economic business of gathering information concerning China's mineral resources. The work had not proceeded far, however, when the directors of the survey realized that they could not carry out this technical program in a way that was satisfactory either to the administrative authorities or to the industrial world without devoting attention also to purely scientific investigation. The study of fossils is of fundamental importance for the elucidation of the geology of the coal fields and of a variety of problems of economic importance. In 1920 the survey was fortunate in securing the cooperation of Dr. A. W. Grabau, formerly professor of paleontology in Columbia University, New York, whose knowledge of invertebrate fossils and broad outlook on the problems of geology have been one of the most important sources of inspiration and guidance of these developments in China.

The importance of the results which these investigations brought to light impressed upon Dr. Ting the need for adequate publication. Hence he instituted the series of memoirs, "Palaeontologia Sinica," in which the results were fully and promptly presented in a way that bears favorable comparison with the best publications in America and Europe.

The Geological Survey has become an important factor in the development of China's resources. Under the directorship of Dr. Wong Wen-hao, who succeeded Dr. Ting, the field work and the intensive research in the laboratories and museum have been continued and further developed.

In the year 1916 Dr. Andersson began his investigations of the Cenozoic deposits of north China and made large collections of fossil vertebrates, for the most part mammals. In the work of examining this material he cooperated with Professor Carl Wiman, of Upsala.

The Site of the Discoveries

The Western Hills, forming the picturesque background to the palaces and temples of Peking, are the scene of the epoch-making discoveries with which I am concerned in this address. The interest of this range, famous for its natural beauties, is enhanced by the multitude of temples and other buildings scattered on its heights and in the recesses of its valleys. Throughout the history of Peking these hills have played an important part in the development of the city. For many centuries the builders of temples and

[2] For all the illustrations I am indebted to Dr. Davidson Black.

palaces have obtained from the Western Hills the supply of beautiful white marble which lends distinction to the architecture of the former capital. Not only did the beauty of this material appeal to the esthetic interest of builders, but the Chinese name "white jade" conferred a sanctity and a magic virtue on this stone, which enormously enhanced its attractions. The builders also resorted to the Western Hills to obtain the limestone from which they get the lime needed for building operations. Hence the people of Peking are well acquainted with this beautiful resort and its petrological resources. About a quarter of a century ago the construction of a branch line from the Pekin-Hankow Railway at a point thirty miles southwest of Peking brought the railway to the village of Chou Kou Tien, to provide a means of transporting coal to Peking from the rich deposits near that village. The building of this railway line served other purposes, for it led to the development of the quarrying of limestone for lime-burning at Chou Kou Tien and thus was responsible for exposing the fossil beds where the remains of the *Sinanthropus* family were found.

In the year 1919, when Dr. Andersson began work in the regions to which these circumstances had directed attention, he found a bone deposit at Chi ku Shan, a name with a meaning ("Chicken Bone Hill") which suggests that the Chinese were aware of the existence of the fossils. Two years later (1921), while excavating fossils on this site he overheard his workmen expressing surprise that he should be spending his time at Chi ku Shan when there was a much richer deposit of fossils nearby. This chance conversation first directed his attention to the site which has yielded such important material. He took the hint and transferred the scene of his excavations to Chou Kou Tien. When he was collecting the early Pleis-

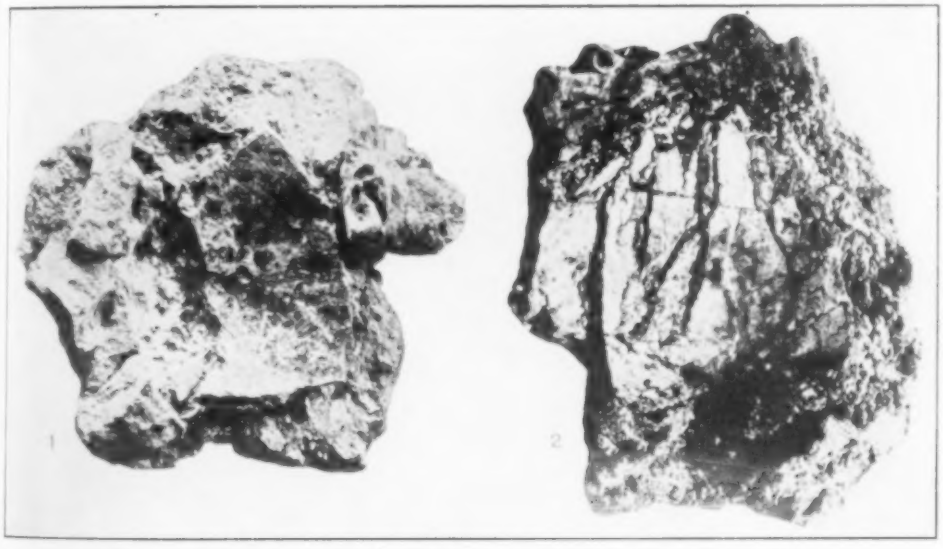


FIG. 2. TWO PIECES OF TRAVERTINE

FOUND AT CHOU KOU TIEN BY DR. BIRGER BOHLIN IN 1928, ONE (1) CONTAINING THE CHIN REGION OF A CHILD'S JAW IN ASSOCIATION WITH FRAGMENTS OF A CHILD'S BRAIN CASE, AND THE OTHER (2) CONTAINING THE FISSURED FRAGMENTS OF AN ADULT PARIETAL BONE.

tocene fossils he found a piece of quartz, a material not known to occur naturally there, and remarked to his assistants: "This is primitive man." For, so he believed, nothing but human agency could have brought this bit of quartz to the early Pleistocene deposit. He had to wait, however, for five years before the evidence was forthcoming which seemed to justify this surprising anticipation. With funds provided by a Swedish patron (Mr. Ivar Kreuger) Dr. Otto Zdansky of Upsala began excavating at Chou Kou Tien in 1922 and took back to Sweden a large collection of material. After examining (in Professor Wiman's laboratory in Upsala) the fossils he had collected four years previously, Dr. Zdansky reported in 1926 the discovery of two teeth, a molar and a premolar, which he declined to define more precisely than *Homo* sp. This discovery excited wide-spread interest when it was publicly announced at the conjoint meeting of the scientific societies of Peking in honor of the Crown Prince of Sweden on October 22, 1926. When writers in the popular press took the bolder course of referring to the original owner of the teeth as "The Peking Man" Dr. Zdansky issued a warning that his discovery "should be regarded as distinctly interesting but not of epoch-making importance." Professor Davidson Black, however, took a different view of the significance of the teeth. He had been profoundly influenced by the memoir published by the late Professor W. D. Matthew in 1915 ("Climate and Evolution," Annals of the New York Academy of Science, Vol. 24, p. 171, 1915). In

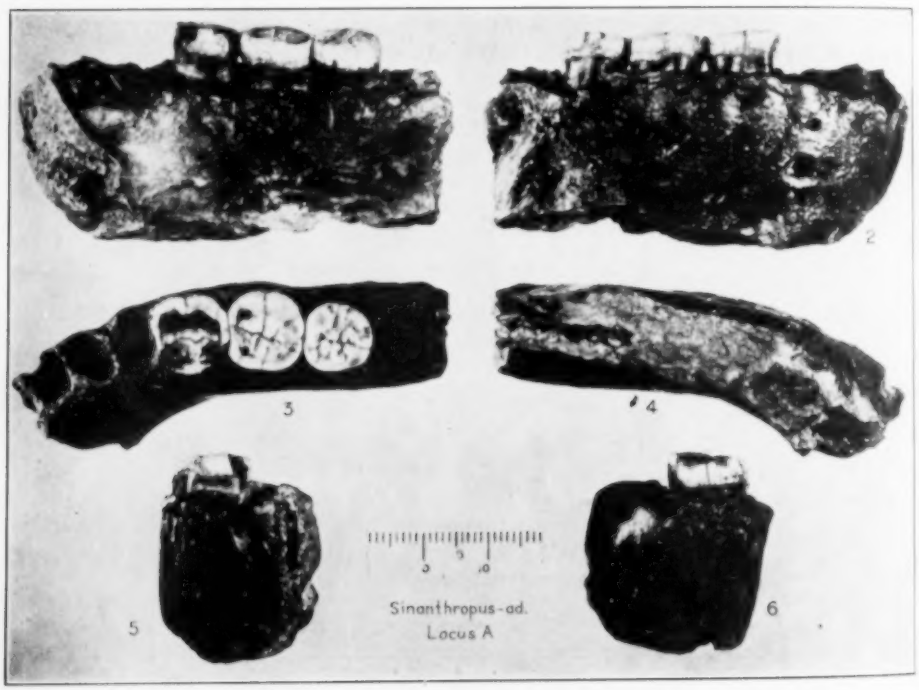


FIG. 3. PART OF AN ADULT MANDIBLE

FOUND ON THE SAME SITE AS THE FRAGMENT (2) SHOWN IN FIG. 2, VIEWED FROM SIX DIFFERENT ASPECTS.

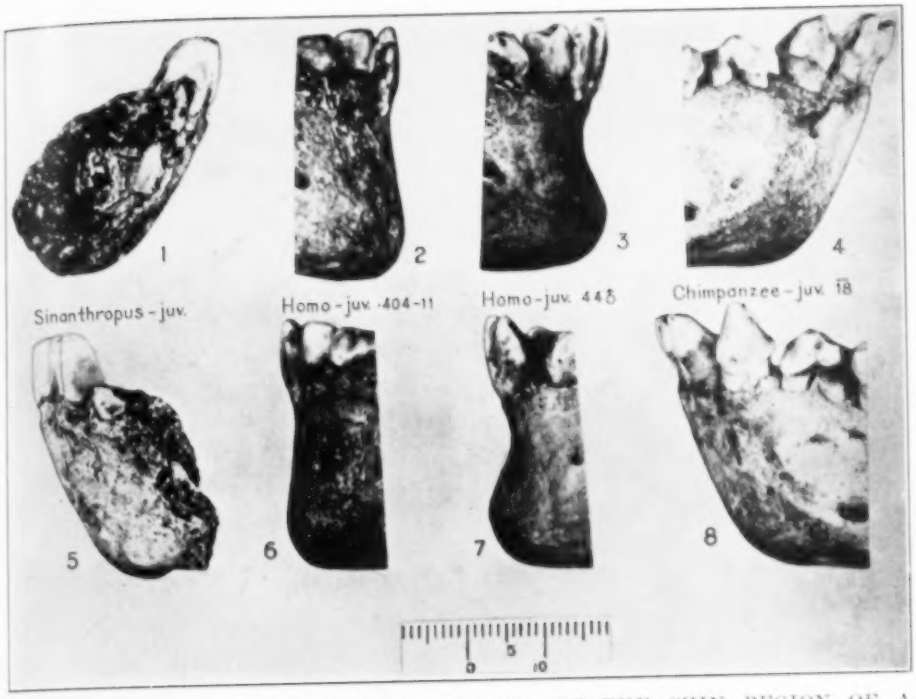


FIG. 4. RIGHT (1) AND LEFT (5) ASPECTS OF THE CHIN REGION OF A *SINANTHROPUS* CHILD

COMPARED WITH SIMILAR VIEWS OF JAWS OF CHILDREN OF CORRESPONDING AGE, NEOLITHIC CHINESE (2 AND 6), MODERN CHINESE (3 AND 7), AND A YOUNG CHIMPANZEE (4 AND 8).

fact, the possibility suggested by Dr. Matthew's argument of the discovery of primitive man in China originally decided Dr. Davidson Black to accept the invitation to join the staff of the anatomy department in the Peking Union Medical College. In 1925 he published a memoir entitled "Asia and the Dispersal of Primates" (Bull. Geol. Soc. China, Vol. IV, No. 2, p. 133, 1925), which revealed the shape his hopes were taking. Hence when Dr. Zdansky a year later found the two human teeth in the early Pleistocene or, as it was then thought, late Pliocene beds, Professor Davidson Black regarded this as a definite realization of the aim which he had set before him several years before, and naturally regarded the discovery as one of momentous importance.

In a communication which, at the request of Dr. Andersson, he made to the scientific meeting held in Peking on October 22, 1926, he emphasized these considerations, and called attention to cogent reasons in support of his belief. The molar tooth found by Dr. Zdansky would seem to resemble in general features the specimen described in 1903 by Professor Max Schlosser. The latter tooth was a left upper third molar having a very much worn crown, extensively fused lateral roots and from the nature of its fossilization considered by Schlosser to be in all probability Tertiary in age. It was provisionally designated as *Homo* (?) *Anthropoide* (?). It is of more than passing interest to recall that Schlosser pointed out that future investigators might expect to find in China a new fossil anthropoid, Tertiary man or ancient Pleistocene

FIG. 5. PHOTOGRAPH OF A CAST OF THE SKULL OF *SINANTHROPUS* EMBEDDED IN THE MATRIX OF TRAVERTINE.

man. The Chou Kou Tien discovery thus affords a striking confirmation of that prediction ("Tertiary Man in Asia," Bulletin of the Geological Survey of China, Vol. 5, 1927, p. 208). To give expression to these convictions, Dr. Davidson Black induced the director of the Peking Union Medical College (Dr. Henry S. Houghton, now dean of the Medical College at Iowa City) and Mr. Edwin Embree, then secretary of the Rockefeller Foundation, to support an appeal to the Rockefeller Foundation for an appropriation to carry on the search at Chou Kou Tien. The late Dr. Richard M. Pearce, at that time director of the medical division of the Rockefeller Foundation, so far appreciated the significance of the possibilities that he induced the Foundation to make an appropriation for two years' work on the site. This project met with immediate success, for on October 16, 1927, Dr. Birger Bohlin found a lower molar human tooth in the deposit at Chou Kou Tien where Dr. Zdansky, in 1922, had found the two teeth reported on October 22, 1926. On December 2, 1927, Dr. Davidson Black announced to the Geological Society of China this important discovery and his courageous decision to use it as evidence for the creation of a new genus and species of the Human Family, which, on the suggestion of Dr. A. W. Grabau, professor of paleontology in the National University of Peking, he called *Sinanthropus pekinensis*. The age of this tooth and the deposits in which all the fossils were found was thought at this time to be Upper Pliocene, but a more careful sifting of the evidence provided by the associated mammals subsequently led the geologists to decide that the real age was Lower Quaternary (very Early Pleistocene). Dr. Davidson Black claimed that the morphology of the tooth left no doubt either of its human

origin or of the fact that it was generically distinct from all other known human types. He came to the conclusion that it was derived from a child corresponding in type to that attained by modern children of eight years, and presumed that it was derived from the same jaw as the lower premolar tooth whose discovery was reported in 1926 by Dr. Zdansky. For it seemed improbable that two children of the same age should have left their teeth on this spot.

At the time (1923) when he was preparing his preliminary report on the geology of Chou Kou Tien, Dr. Andersson was impressed by the presence of fossil remains of a true horse and the absence of *Hipparion* and, like Professor Schlosser in 1903, suggested the possibility of the fossil beds, which were definitely earlier than the loess, being of Upper Pliocene age. As a fuller knowledge of the extinct fauna of Eastern Asia was acquired, however, it became abundantly clear (at the close of 1927) that the geological age was Early Pleistocene. The evidence and the arguments have been set out with great lucidity and convincing cogency by Père Teilhard and Dr. C. C. Young in their "Preliminary Report on the Chou Kou Tien Fossiliferous Deposit"

FIG. 6. UPPER ASPECT OF THE PEKING SKULL.

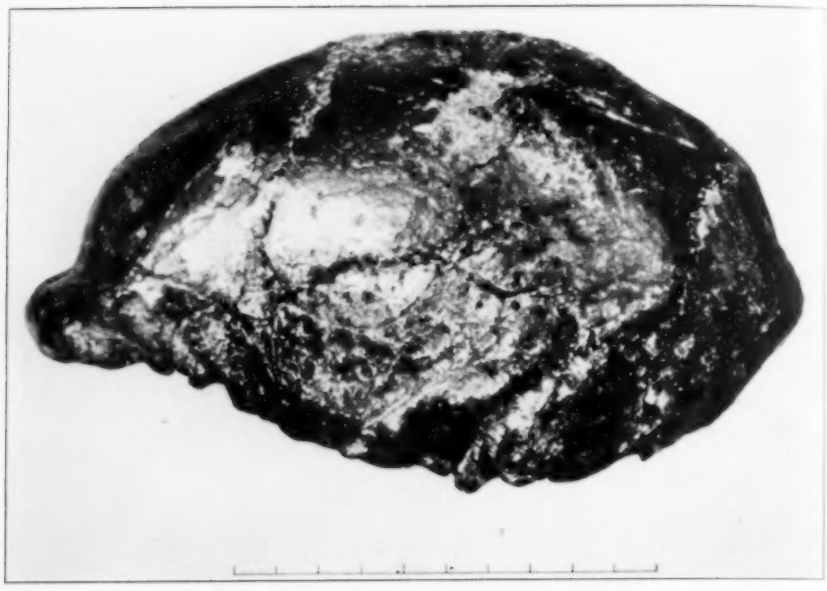


FIG. 7. LEFT SIDE OF THE PEKING SKULL.

(*Bulletin of the Geological Society of China*, Vol. VIII, No. 3, 1929). The absence of truly archaic forms, such as the big *Hipparion*, *Chalicotherium*, et cetera, and the presence of horses and deer with more recent characters proved that the beds were more recent than Pliocene. The absence of fauna characteristic of the Middle Pleistocene loess —*Rhinoceros tichorhinus*, *Bos primigenius*, *Hyaena crocuta*, *Cervus elaphus*, et cetera—and the presence of earlier forms established the proof of its Early Pleistocene age.

The morphological characters of the tooth thus shown to be Early Pleistocene in age suggested that it was more nearly akin to those of the Hominidae than to those of the Simiidae, and the nature of the wear of the tooth afforded important corroboration of this inference. In spite of these considerations, which were set forth with restraint and impressive cogency in an exhaustive monograph ("Palaeontologia Sinica," Series D, Vol. VII, 1927), Dr. Davidson Black's boldness in creating a new genus on the evidence of one tooth gave rise to wide-spread criticism.

A year later, however, in November, 1928, Dr. Birger Bohlin, working in conjunction with Dr. C. C. Young and Mr. W. C. Pei, found additional remains of human skulls which provided justification for the action Dr. Davidson Black had taken in the previous year. In addition to further teeth conforming to the *Sinanthropus* type the material found in 1928 included portions of two lower jaws and fragments of brain-cases, which probably belonged to the same individuals as the mandibles. The peculiar features of the chin region of these jaws differed from those of all other known human specimens excepting only the Piltdown jaw, to which they presented a general resemblance, without being generically identical. There is a similar ape-like obliquity in the slope of the symphysis and traces of the simian shelf on the lingual aspect of the jaw. Not only do these peculiarities

emphasize the peculiar features of *Sinanthropus*, but they also afford welcome confirmation to the views of those who regarded the Piltdown jaw as human. The fact that mandibles with such an ape-like conformation of the chin region were found at Chou Kou Tien in association (Fig. 2) with broken remains of human brain-cases provided valuable evidence in support of the view that the jaws also were human. Hence they contributed weighty support to those who regarded the Piltdown jaw, which had been a matter of controversy for sixteen years, as really a part of the same individual as the brain-case found in association with it.

The importance of the work accomplished during the two years covered by the first appropriation of the Rockefeller Foundation led, in 1929, to the renewal of the grant and the creation of a special department, the Cenozoic Research Laboratory, of the Geological Survey of China, under the honorary directorship of Professor Davidson Black. This significant action was due in large measure to the support of Mr. Roger Greene, the executive head of the Peking Union Medical College.

The confidence which was implied in the granting of the new appropriation was immediately justified by the most impressive and significant discovery in the whole history of human palæontology. At four o'clock on December 2, 1929, Mr. Pei found an uncrushed and almost complete brain-case of *Sinanthropus*. The skull was embedded in a mass of travertine, from which it took Dr. Davidson Black four months to free the skull, a tedious and difficult operation, which required exceptional care and technical skill to accomplish by means of dental drills. There still remained the task of removing the hard mass of travertine which filled the cranial cavity. Dr. Black was anxious not to destroy this natural endocranial cast, and fortunately the skull was that of an adolescent and its sutures were still unclosed. Not only so, but the bones were cracked so that he was able to remove the parietal bones in pieces and examine the texture of the cranial wall.

FIG. 8. FRONT OF THE PEKING SKULL.

FIG. 9. POSTERIOR ASPECT OF THE PEKING SKULL.

The bones were surprisingly thick and comparable to those of the Piltdown skull both in structure and thickness. It was found possible to remove the frontal, occipital and temporal bones from the surface of the endocranial cast and then reconstitute each of the bones of the skull, so that they could be examined in the way customary among students of the modern disarticulated skull. The bones so successfully disarticulated by Dr. Davidson Black were then fitted together again to reconstitute the skull, from which an artificial endocranial cast has been made.

This important mould of the brain-case can not be further discussed until Dr. Davidson Black has published his official report and photographs of it. It will then provide evidence of profound significance on the problem of how man acquired the distinctive qualities of his brain, which conferred upon him the mental preeminence which made him human.

The fossil is important not merely because it gives a reliable idea of the exact form of the skull of an early Pleistocene man (free from the doubts which arise in the case of a reconstructed specimen), but also because its peculiar features, revealing as they do many points which suggest an affinity with *Pithecanthropus*, associated in the same skull with others such as are known only in the case of the Piltdown skull, form a bond of union between the other two early Pleistocene skulls, the characters of which hitherto have been supposed to be irreconcilable one with the other. In addition to this, the skull of *Sinanthropus* reveals many features which are unknown in either of the other types and throws a great deal of light upon the characters of the common ancestor of the human family, from which all these genera had been derived. One of the most striking illustrations of this fact is the peculiar form of the mastoid region of the temporal bone, recalling as it does the condition found in the newborn child and in the adult anthropoid apes. For it lacks that salient character which is so distinctive of the adult human being in other genera.

The brain-case which was found is that of a young adult corresponding in

the state of its development with the condition found in modern human skulls at about sixteen years of age. When the skull was first examined Professor Davidson Black was impressed by the grace of its contours in comparison with the uncouth outlines of *Pithecanthropus*, and suggested the possibility that it might be female, with the reservation, of course, that the evidence at our disposal regarding this hitherto unknown type of being was altogether inadequate for any definite decision upon this matter. Its grace, however, may be due to its primitiveness and the fact that it is free from those secondary distortions which give the degenerate *Pithecanthropus* its bizarre character. The discovery of another brain-case was made in July, 1930, by recovering from material brought in from the Chou Kou Tien cave (in October, 1929) a series of fragments which articulated one with the other to form the greater part of the calvaria. This discovery of a skull of another adult at least ten years older than the one found in December, 1929, revealed a more lightly built skull with smaller eyebrow ridges, a less prominent forehead and less obtrusive parietal eminences, which both Professor Davidson Black and I consider to be probably of different sex to the other skull. It seems not unlikely, however, that the skull reported in July, 1930, may prove to be female and the other skull (found on December 2, 1929) male: but at present neither opinion can be said to be based upon any really decisive evidence. The discovery of a second skull enormously

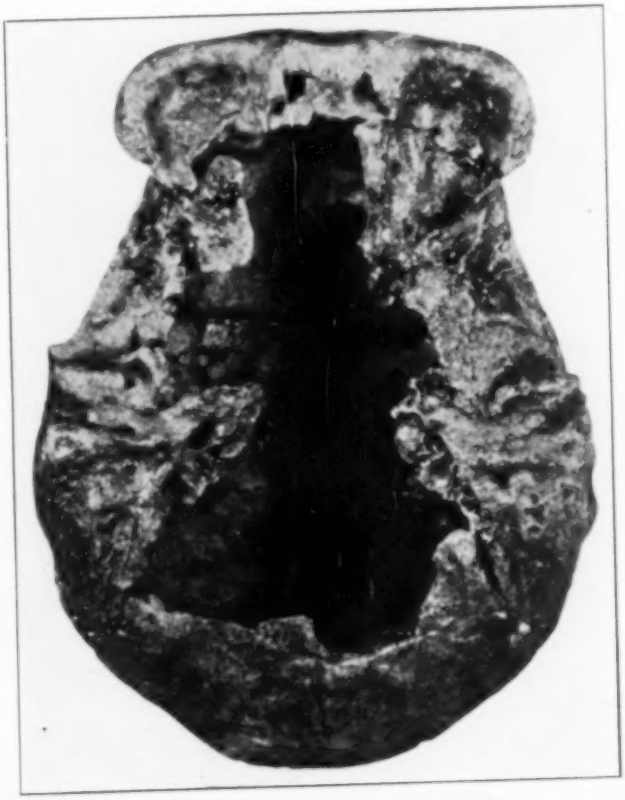


FIG. 10. UNDER SURFACE OF THE PEKING SKULL.

FIG. 11. THE UPPER ASPECT OF THE ADOLESCENT SKULL OF *SINANTHROPUS* × ½

WITH PARTS OF THE PARIETAL BONES AND A SMALL PART OF THE LEFT SIDE OF THE FRONTAL REMOVED TO REVEAL THE NATURAL ENDOCRANIAL CAST. THE GREAT THICKNESS OF THE CRANIAL WALL AND THE CORRESPONDINGLY DIMINUTIVE SIZE OF THE CRANIAL CAVITY IS SHOWN. ON THE RIGHT SIDE (JUST ABOVE THE SQUAMOUS SUTURE) SEVERAL FLAKES OF STONE AND THE TOOTH OF A CAVE BEAR CAN BE SEEN EMBEDDED IN THE ENDOCRANIAL MASS OF TRAVERTINE.

enhances the value of the information we have because it permits comparisons to be made. In the material found in 1928 (Fig. 2) there are remains of two other broken skulls (still embedded in travertine), which provide other important comparative material for studying the range of variation of the skulls. One of the most remarkable points of contrast between the brain-case of *Pithecanthropus* and of *Eoanthropus* is the phenomenal thickness of the latter, whereas the skull of *Pithecanthropus* is much thinner. In the case of the skull of *Sinanthropus* found on December 2, 1929, the thickness of the bone approximates to that of the Piltdown skull. Not only does it resemble it in mere thickness, but the architecture of the cranial vault (which in the case of the Piltdown skull has hitherto been regarded as quite distinctive) is almost exactly reproduced in the case of *Sinanthropus*. In all other known human skulls the cranial bones consist of two fairly thick tables united by a comparatively thin layer of diploic tissue consisting of fine trabeculae. In the case of the thick cranial bones of both the Piltdown and the Peking skulls, the tables are relatively thinner and the thicker layer of diploic bone consists of a very robust network of coarse trabeculae. These similarities suggest that in the thickness and peculiar texture of the cranial bones of two early Pleistocene skulls of different types (separated geographically as their habitats were by the whole extent of the continental land mass between England and China) we are dealing with characters of primitive man for which no close analogy can be found in the apes. This condition in the Piltdown skull was regarded either as pathological or the result of some freakish mutation. But the presence of the same condition in *Sinanthropus* enhances its importance. Why the skull of primitive man should attain such an enormous thickness is difficult to explain: but the evidence provides an interesting problem for morphologists to endeavor to solve.

Did primitive man's skull increase in thickness because the increase in the capacity of the brain-case deprived an increasing area of the protection of the temporal muscles? Or was it because this exposed area of skull was liable to new kinds of risks when men began to use sticks and stones as weapons? These tentative suggestions are much too speculative to be seriously discussed.

Yet there must be some definite explanation of the increased thickness of the skull of primitive man when his expanding brain seems to need more ample protection than the ape enjoys—a thicker cranium with an ampler supply of bone marrow, which his descendants seem to have found unnecessary. For the moment, however, when there is no clear indication as to the meaning of this peculiar morphological feature, it is of interest as emphatic evidence of the affinity between *Eoanthropus* and *Sinanthropus* and of the enhanced importance of the structural peculiarity itself. The contrast in thickness between the cranial vault in *Pithecanthropus* and *Eoanthropus* acquires a new interest in view of the fact that the three (adult) skulls of *Sinanthropus* (one of the fragments found in 1928 is thin because it is part of a child's skull) reveal a considerable range that is sufficient to bridge the gap which separates Piltdown Man from the Ape Man of Java. These interesting morphological features are merely one illustration of a series of interesting facts revealed by the discovery at Chou Kou Tien.

I have already referred to the fact that the discovery of the two jaws in 1928, presenting as they did features hitherto known only in Piltdown Man, raised the possibility that there had been discovered in China a type of human being more closely akin to the Pleistocene man of England than that of the Ape Man of Java, who was geographically much nearer to the Peking Man. When, however, in 1929, the skull was found (and the base was still embedded in the solid mass of travertine) the striking resemblances of the brain-case to that of *Pithecanthropus*

FIG. 12. RIGHT SIDE OF THE SAME SPECIMEN × APPROX. ⅓
DISPLAYING IN AN EVEN MORE STRIKING MANNER THE EXCEPTIONAL THICKNESS OF THE FRONTAL AND PARIETAL BONES.

FIG. 13. LEFT LATERAL ASPECT OF THE FEMALE SKULL OF *SINANTHROPUS*.

suggested after all the newly found genus was more nearly akin to his neighbor from Java. The skull revealed great projecting eyebrow ridges like those of *Pithecanthropus*, which provided a marked contrast to the condition found in Piltdown Man in which such ridges were lacking. The front part of the skull was also flattened and ill-filled, and had a prominent median crest such as that of *Pithecanthropus*. There was the difference in the frontal region of the bone, however, that the frontal eminences were definitely more obtrusive than those of *Pithecanthropus*. Turning to the consideration of the parietal bones one finds a close resemblance to those of the Piltdown Man. This resemblance depends both upon the fact that the bones tended to be raised up towards the middle line and are not so flat as those of *Pithecanthropus*, that there is a very definite parietal eminence such as is completely lacking in the Java skull, and the postero-inferior corners of the parietal bones are everted in that peculiarly distinctive way found in the Piltdown skull. The occipital bone again presents a much closer resemblance to that of *Pithecanthropus*, and when we turn to consider the temporal bones we find a much more primitive condition of the mastoid and of the tympanic bones than that which is revealed in *Eoanthropus*. Unfortunately the temporal bone of *Pithecanthropus* had not yet been discovered, so that we can not institute comparisons between *Sinanthropus* and *Pithecanthropus* in this respect. One of the most interesting features of the specimen found in 1929, a feature which Dr. Davidson Black inferred from the nature of the wear of the teeth long before the skull was found, is the fact that the condyloid fossa for articulation

with the mandible presents a very close resemblance to the condition found in modern man, both in size, depth and direction. This fact is all the more remarkable because in other extinct members of the human family, in particular Rhodesian Man and Neanderthal Man, there are much more profound differences in the under surface of the temporal bone. The preservation of the condition which became a permanent factor in *Homo sapiens* suggests that the *Sinanthropus* is a primitive generalized type and that modern man has retained many of these primitive characters. Looking at the skull as a whole, one can say that its general form is intermediate between the conditions found in *Pithecanthropus* and *Eoanthropus*. It enables us to unite into a solid foundation the characters of the three most primitive members of the human family at present known. In giving coherence to this knowledge it also enables us to picture the nature of the common ancestor of all three, the as yet hypothetical Pliocene Man.

The suggestion has been made that the Peking Man's distinctive features are not sufficiently pronounced to exclude him from the genus *Pithecanthropus*. When the skull was still embedded in the mass of travertine, its similarity to the calvaria of *Pithecanthropus* impressed most of those who saw the photographs of it (Fig. 5). But, as Dr. Davidson Black pointed out in 1929, the fulness of the frontal and parietal eminences afforded definite evidence of its generic distinction. Since it has been extracted from the matrix, the contrast between the skulls (and in particular the endocranial casts) is revealed in a more emphatic way. Hence it is unfortunate that several paleontologists (for example, Dr. Hans Weinert, "Menschen der Vorzeit," Stuttgart, 1930, p. 39), in Germany and elsewhere are expressing the opinion that the Peking Man should be included in the genus *Pithecanthropus*.

The whole configuration of the skull, the texture of the cranial bones, the morphology of the frontal, parietal and occipital bones, as well as the distinctive features of the teeth and mandible clearly differentiate Peking Man from the Ape Man of Java and present a contrast which is so profound as to compel us to accord it generic distinction. In many respects it differs from *Pithecanthropus* and resembles *Eoanthropus*, but the contrast to the latter is even more obtrusive. It occupies an intermediate position between the two, but is more primitive and generalized than either.

Further discoveries of remains of *Sinanthropus* are still being made at Chou Kou Tien, and during the next couple of years we can only hope that the flair which the young Chinese geologist, Mr. W. C. Pei, has shown in his epoch-making discoveries, in 1929 and 1930, will lead to the finding of still more important remains of the most primitive and illuminating type of archaic men so far revealed.

Whether or not the Peking Man was older than the fossils found in Java and Sussex, there was no doubt that he represented a more primitive type. His characters were more generalized, some of them distinctly reminiscent of man's simian ancestry and others strangely foreshadowing the qualities hitherto regarded as distinctive of *Homo sapiens*. In other words, *Sinanthropus* enabled us to picture the qualities of the original members of the human family by revealing a type which, though human, was curiously ape-like, and obviously close to the main line of descent of modern man.

The work of investigation and of recording the results of the work has been carried on with exceptional thoroughness and imaginative insight. It was

hoped by Dr. Davidson Black that the prompt publication of bulletins and the wide circulation of the manuscript reports even before they were published, would have prevented the development of such misunderstandings as had marred the discussions of the fossil remains of man in the past. In spite of these precautions, eminent paleontologists in Germany and France are already claiming that the Peking Man belonged to the genus *Pithecanthropus;* others in America have suggested that he was only a Far Eastern example of Neanderthal Man; and others again that the Chinese fossils were not human.

Having just made a careful examination of the actual fossils in Peking and compared them with human and simian skulls and the casts of the other kinds of extinct members of the human family, I can confidently support the opinion of Dr. Davidson Black that *Sinanthropus* was an undoubted member of the human family who revealed in every quality of his skull evidence to distinguish him from all other known human types, and to justify the separate generic rank suggested to define his status.

The Cradle of the Human Family

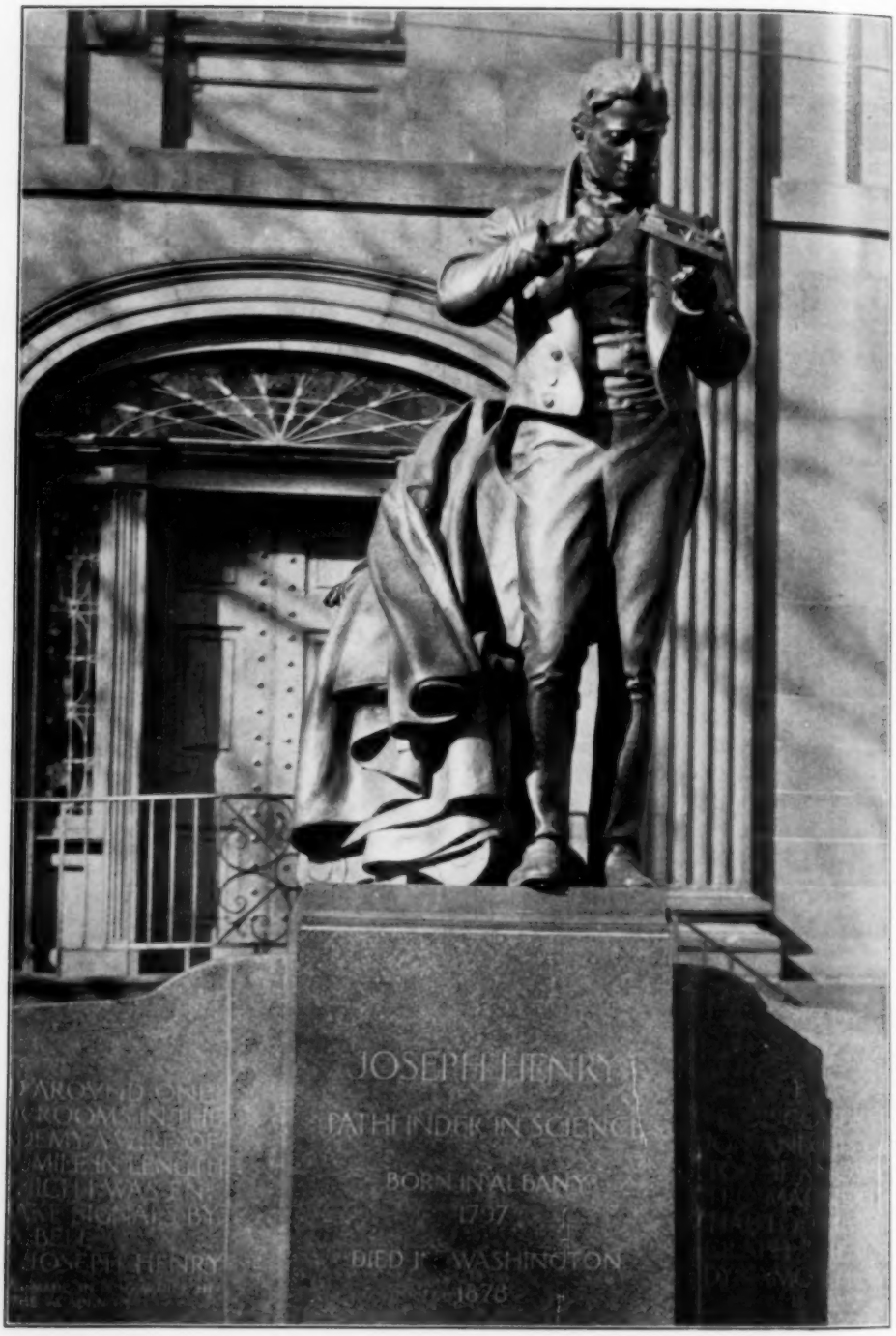
It has been assumed by certain writers that the discovery of this skull in eastern Asia and the earlier finding of *Pithecanthropus* in Java afford definite grounds for locating the original home of the human family in Asia. I should like to take this opportunity of pointing out that the evidence affords no warrant for such an interpretation. Long ages before the human family came into existence the anthropoid apes had wandered up and down the vast continental mass ranging from western Europe to eastern Asia and to the heart of Africa. The distribution of the Miocene and Pliocene fossil remains of *Dryopithecus* and of *Pliopithecus* and the discovery in South Africa of the ape Professor Dart has called *Australopithecus* (to which Dr. Robert Broom now assigns an age of the early Pliocene) revealed the fact that the anthropoid apes, more profoundly hampered in their range of movements than are human beings, and less able to adapt themselves to different environments, were able to roam from one end of the area occupied by primitive man to the other, probably millions of years before man himself appeared upon the scene. Hence the finding of fossil remains of early Pleistocene man in England, China and Java does not necessarily throw any light upon the home of the much earlier (Pliocene) common ancestor of these three genera, seeing that ample time was allowed for the much nimbler and more rapidly migrating human members of the Order to roam from one end of the territory to another. Seeing that the common ancestors of the anthropoid apes and men probably occupied northern India during the Miocene Period, and that the members of that family displaying the closest affinity to man, namely, the African anthropoids, the gorilla and chimpanzee, *Dryopithecus* and *Australopithecus*, all wandered to the west, I am inclined to accept the view expressed in 1871 by Charles Darwin that, while evidence is not yet available to answer the question, Africa seems to be a more likely home for the human family. Professor A. W. Grabau has revived ("Asia and the Evolution of Man," *The China Journal*, Vol. XII, 1930) the old suggestion, based upon the climatic changes induced in Asia by the upraising of the Himalayas at the close of the Oligocene, in favor of the likelihood that man's Miocene ancestors may have found in the Tarim Valley (or elsewhere in Chinese Turkestan) ideal conditions to stimulate their progressive evolution. I fully recognize the cogency of his arguments and the brilliant per-

suasiveness of his exposition, and am quite ready to be converted to his views if and when positive evidence in corroboration of them is forthcoming.

The series of fossil remains of man which are now available provide very significant evidence in the casts of their cranial cavity of the changes which were occurring in the brain to confer upon *Homo sapiens* the skill upon which the attainment of wisdom so largely depends. For although no one would assume that we have yet found a linear series of ancestors, at the same time by comparing the form of the endocranial cavity in the various extinct members of the series we can detect a progressive expansion of the brain in an orderly fashion which is of particular interest because it agrees with the order in which the cortical areas in the brain of the growing child reach their maturity and their full functional significance. We are gradually acquiring from the study of the endocranial casts of fossil men in comparison with those of the anthropoid apes and human children some light upon the essential differences between the brains of apes and men. It now becomes a matter of special interest to interpret the processes which went on in the brain to confer upon man his supreme distinction—the human intellect.

The Absence of Artefacts

In studying the remains of early man it is always a matter of particular importance to search for the tools and implements which might bring the human beings into association with some definite phase of industry. It is a very significant phenomenon that at Chou Kou Tien, in spite of the most careful search in the caves during the last three years, no trace whatever of implements of any sort has been found. When it is considered how vast a quantity of fossil remains has been found and the scrupulous care which has been exercised in the search, it must be something more than a coincidence that no trace of any stone implements has been found. Not only have the various excavators been on the constant lookout for such artefacts (in particular, Father Teilhard de Chardin has been looking for archeological evidence), but after the material was removed from the caves, a group of boys was set to sift the material once more to make quite certain that no such evidence had been overlooked by the geological explorers. It must not be forgotten, however, that Dr. Andersson, in 1921, found pieces of quartz in association with the fossil bones, and that in the later stages of the excavation Mr. Pei found further examples of this alien material. Those who have been searching in vain for evidence of human craftsmanship on this site are being forced to the conclusion that the Peking Man was in such an early phase of development as not yet to have begun to shape implements of stone for the ordinary needs of his daily life. Whether or not he made tools of wood or other perishable material it is impossible to say, but presumably the chances are that a creature who had acquired the type of brain which is distinctive of the human family, the development of which is intimately associated with the growing skill and understanding, would have used implements of some sort, if nothing more than sticks, to protect himself and to obtain food either by digging or by killing animals.



—Photograph from the New York State Museum

THE JOSEPH HENRY MONUMENT

RECENTLY UNVEILED IN ALBANY. IN THE BACKGROUND IS THE ALBANY ACADEMY WHERE JOSEPH HENRY MADE HIS IMPORTANT DISCOVERIES IN ELECTROMAGNETISM.

JOSEPH HENRY

By EDITH W. STONE
PHILMONT, NEW YORK

JOSEPH HENRY, American physicist, was born in Albany, New York, on December 17, 1797. Many books give the date of birth as 1799, but it is the former date which appears in the official baptismal records of the First Presbyterian Church of Albany, founded in 1763. Henry was of Scotch descent, his ancestors, both maternal and paternal, having come over from Scotland on the same boat just prior to the battle of Bunker Hill. Little is known in regard to this father, William Henry, though we do discover that he was a day laborer and that he died when the lad was about ten. Many years later Henry wrote in a letter to Professor A. M. Mayer, one of his associates: "I have been sorry that my grandfather, in coming from Scotland to this country, substituted it (the name Henry) for Hendrie, a much less common, and therefore more distinctive name."[1] This would seem to indicate that the inability to trace the early history of the Henry family was due in part to the change in name. Henry's mother, Ann Alexander, is described as a woman of marked refinement and gentle mien. Caroline, Henry's daughter, thought that the Alexanders originally came from Argyleshire, Scotland, and that the family were descendants of the Earl of Stirling.[2] Beyond these few isolated facts, the writer was unable to trace the genealogy of either the Henry or the Alexander families.

At an early age Joseph left Albany, for what reason is not known, and made his home at Galway with his uncle. This man, John Alexander, was a twin brother of Henry's mother. In this small town the boy attended the country school, but he was in no way an unusual scholar, as he applied himself to his work in a more or less desultory way. It was due to the following peculiar experience that a change was effected in his hitherto uneventful life. Among other animals on the farm, Joseph had a pet rabbit which caused him many unhappy moments because of its various expeditions to neighboring fields and gardens. One day, while in pursuit of this exploring animal, Joseph saw it disappear within the cellar wall of the village meeting house and church. The boy at once removed a few more stones from the broken wall and followed the rabbit within, but seeing a book that had fallen through the timbers to the cellar floor, he immediately forgot the errand that had brought him there. The book happened to be Brook's "Fool of Quality," and was but one of several books which the boy presently discovered in a case in the small library on the floor above. From the perusal of this book of fiction dated Joseph's love for reading. At that time, when school hours were over, the boy acted as clerk and general helper in the village store, but during his free hours he made frequent use of his secret entrance to the library. Here he read books of romance and thrilled over the experiences described therein. His employer, as soon as he learned of the boy's awakened interest in reading, procured him entrance through legal channels, with the result that Joseph brought his books to the store in order that both he and his

[1] Published by Order of Congress: "A Memorial of Joseph Henry," 1880, p. 507.

[2] Wm. Henry Eldridge, "Henry Genealogy," with appendix containing brief accounts of other Henry families, 1915, p. 128.

employer might spend many hours reading and talking over the contents of the various volumes.

Life went on in this manner until Joseph was about fifteen, when he returned to Albany to live with his mother. Here he was apprenticed to a watchmaker until this man failed in business. His next venture, generated no doubt by his reading of fiction, was in connection with play producing. For the better part of a year he turned his attention to the stage; he worked out stage setting effects, and he even wrote a play in which he took one of the parts. He was not destined, however, to become an actor, as his next endeavors, set in motion by reading while he was ill a book on natural history (Dr. Gregory's "Lectures on Experimental Philosophy, Astronomy, and Chemistry") took him into the scientific world. He now realized that his capacities and inclinations pointed to a field of work far removed from the stage, and to better fit himself for a higher position in life he began to attend night classes. Later he entered Albany Academy, where he paid his expenses by teaching in country schools and by tutoring in the city. After his course of work at the academy was finished he tutored for a time in the Van Rensselaer family. He nevertheless kept up his studies in chemistry, anatomy and physiology, as it was his intention to study medicine at a later date. But in 1825 he was sent out to make a survey for a state road, and in his new enthusiasm for this pursuit he decided at once to make engineering his life work. The next year, however, he was offered the position of professor of mathematics at Albany Academy, an appointment which he accepted immediately. Although his work here required many hours of exacting duties, he still found time to do research work, and it was here he began the experiments that resulted in the development and perfection of the electromagnet. One principle worked out by Henry and established during his professorship at the academy was that of the electromagnetic motor. His next work was in connection with the electric telegraph, for by bringing into use his electromagnet, he made possible the transmission of power at a distance. Just before he terminated his connection with the academy, he discovered electromagnetic induction.

Four years after he accepted the professorship at Albany Academy, in 1830, he married his cousin, Harriet L. Alexander, of Schenectady. Six children resulted from this union, three of whom were living at the time of Henry's death. Mrs. Henry died in 1882, four years after the death of her husband.

In 1832, Henry was offered the chair of natural philosophy at the College of New Jersey (now Princeton), a position that he occupied for fourteen years. During this time he became much interested in the problem of education, which he thought should include "training for both the observing and reasoning faculties";[3] the method of training he emphasized was that of "philosophical investigation." It was during these years at the College of New Jersey that Henry investigated thoroughly the higher orders of induction, which led to his independent discovery of the phenomena of wireless telegraphy.

To go back a few years, I should like to mention James Smithson, an English chemist, whose death occurred in 1829. According to the terms of his will, he bequeathed funds "To Found at Washington, D. C., an Establishment for the Increase and Diffusion of Knowledge among Men." This institution, not actually established until 1846, became the center of much of Henry's later

[3] Published by Order of Congress: "A Memorial of Joseph Henry," 1880, p. 62.

work, as he was chosen for its first secretary and held this position until his death in 1878. More will be said about this institution later.

Due to Henry's work at the three places of learning with which he was intimately connected, and for the reason that he helped to develop the science of electricity more than any other American, he earned the reputation of being one of the greatest of experimenters. Cuyler Reynolds, in writing of Henry's achievements, says that he perfected more than one thousand actual experiments.[4] At the time of Henry's appointment as secretary of the Smithsonian Institution, Sir David Brewster, a Scottish physicist and president of the British Association for the Advancement of Science, made the following statement, indicative of the high standing of the American: "On the shoulders of young Henry has fallen the mantle of Franklin."[5] During his professorship at Albany Academy, Henry began his first real experimenting that resulted in the development of the electromagnet. We know the electromagnet as a core of soft iron which becomes a magnet temporarily when an electric current is passed through a coil of wire surrounding it. In 1827, when Henry first started his work, an electromagnet of very simple design, invented by Sturgeon, was in use. This was merely a piece of soft iron bent into the shape of a horseshoe and then varnished to furnish insulation, after which a piece of wire was wound about it, as shown in Fig. 1. This instrument did not prove to be much of a magnet, so Henry began working to develop a more powerful electromagnet. He first insulated the conducting wire with silk thread, then he wound it around the iron bar very closely in order to have a greater amount of wire through which the current could pass. Hitherto no one had used covered wire, and the single layer of naked wire used was insulated from the iron core and each turn of wire from the next, by a layer of sealing wax. Fig. 2 illustrates Henry's principle. By further original ideas in the construction of his apparatus, he succeeded in making electromagnets of still greater power and effectiveness. His improvement included a longer insulated wire than had been used before; instead of using only one layer, he wound one over the other, inserting a piece of silk between the layers to make the insulation greater. Instead of a single helix around the bar of iron, he constructed a compound helix, that is, he wound about the bar many coils, leaving the ends free. (See Fig. 3.) These ends were then soldered to allow for the distribution of the current among the coils in such a manner that the effect of different distributions of current could be tested. Much credit is due Henry for the development of this magnet, because it was most helpful to him in his discovery of the methods of winding necessary to perfect the quantity and the intensity magnets.

Electromagnets constructed on this plan are still used, as is also the spool magnet—the principle of which belongs to Henry—whereby the wires are wound on spools that slide up and down on the bar, as shown in Fig. 4. Mr. Wm. B. Taylor said, in speaking of this spool magnet:

> Not until after the publication in January of 1831 of Henry's experiment was it ever employed by *any* European physicist.[6] Henry is also credited with the experiment that demonstrated the difference between the quantity magnet and the intensity magnet, the latter of which he used in constructing the apparatus for his electric telegraph. Some years later his daughter, Mary, in speaking of her father's work, said: "He married the intensity magnet to the intensity battery, the quantity magnet to the quantity battery, discovered the law by

[4] Cuyler Reynolds, "Albany Chronicles," 1906, p. 682.

[5] George B. Goode, "The Smithsonian Institution 1846–1896," 1897, p. 122.

FIG. 1. THE STURGEON MAGNET. FIG. 2. THE HENRY MAGNET. FIG. 3. MAGNET WITH COMPOUND HELICES.

which their union was effected, and rendered their divorce forever impossible.[6]

Henry very early foresaw the possibility of building a machine whereby he could get power from an electric current; and, as there were no dynamos at that time, he had to depend upon primary batteries. After some experimenting, he finally (1829) constructed the first electric motor, and equipped it with the first automatic commutator ever used. His method of construction was as follows: An electromagnet, pivoted at the center, was placed horizontally, with its terminals bent to form contacts, when charged, with two vertical magnets. Around the electromagnet were wound copper wires, the uncovered terminals at either end of the magnet projecting and bending to dip into two mercury cups. Then, as the electromagnet swung and tipped, it made a contact with one battery, while at the same time the other end was free and unconnected. However, the current produced by this contact made the magnet tip in the other direction, breaking the connection with the first battery as it was established with the second. This caused the magnetism in the magnet to reverse, with the result that it again tipped back to its former position. Fig. 5 illustrates the method of construction. Henry, although he said this motion back and forth was produced by "magnetic attraction and repulsion," did not consider his experiment to be of much importance. He spoke of his motor as "a philosophical toy; although in the progress of discovery and invention it is not impossible that the same principle, or some modification of it on a more extended scale, may hereafter be applied to some useful purpose."[8]

A third experiment Henry worked upon at the Albany Academy in 1830 was in connection with the electric telegraph. In this experiment he used a permanent magnet, pivoting it at the center in order to allow of free play. Over this was an electromagnet with the permanent magnet so arranged that, in

[6] George B. Goode, "The Smithsonian Institution 1846–1896," 1897, pp. 124 and 123.

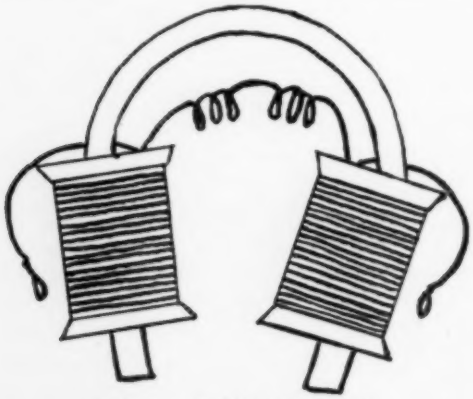


FIG. 4. SPOOL MAGNET.

[7] Published by Smithsonian Institution: "Scientific Writings of Joseph Henry," Vol. I, 1886, p. 56.

[8] Published by Smithsonian Institution: "Scientific Writings of Joseph Henry," Vol. I, 1886, p. 54.

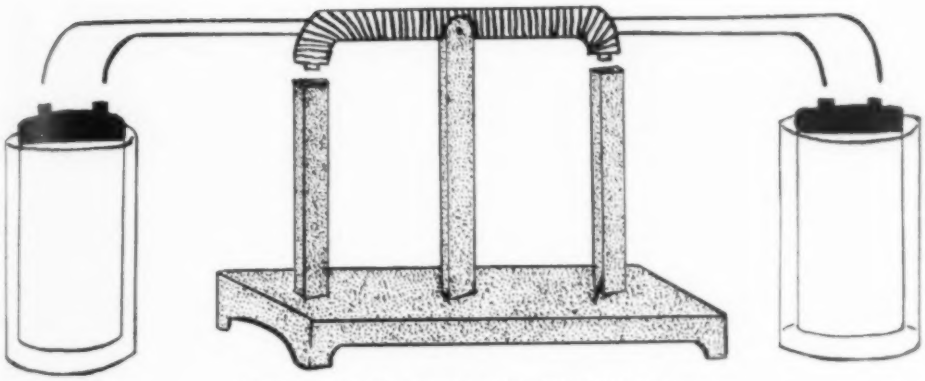


FIG. 5. ELECTROMAGNETIC ENGINE.

pivoting, one of its ends would come to rest midway between the two poles of the electromagnet. The rest of the apparatus consisted of a switch, used in reversing the connections of the electromagnet, and a bell, so located that the permanent magnet, when it moved, would strike against it.[9] In working out this experiment, Henry caused the current to be sent through a mile of fine copper wire. The result was that the little bell actually rang, making an audible signal, and this pointed out the possibility of instantaneous transmission of news between distant points by means of an electromagnetic telegraph. Fig. 6 shows the arrangement of the apparatus used in performing the experiment.

[9] Published by Smithsonian Institution: "Scientific Writings of Joseph Henry," Vol. II, 1886, p. 434.

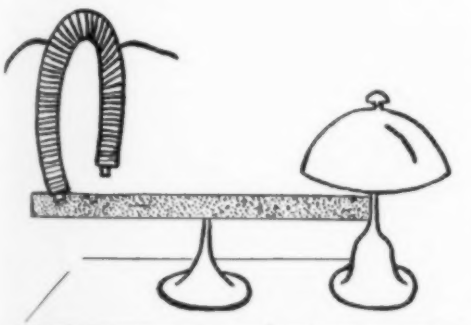


FIG. 6. ELECTROMAGNETIC TELEGRAPH AND BELL SIGNAL.

So to Henry, and not to Morse, belongs the principle and construction of the first electromagnetic telegraph. Morse did, however, develop the possibilities of Henry's principle, for which due credit is given to him. Before he became involved in patent litigation,[10] Morse freely acknowledged his indebtedness to Henry, for he did make use of Henry's intensity magnet, as well as of Henry's device of the telegraph relay, in perfecting his own apparatus. T. C. Mendenhall says:

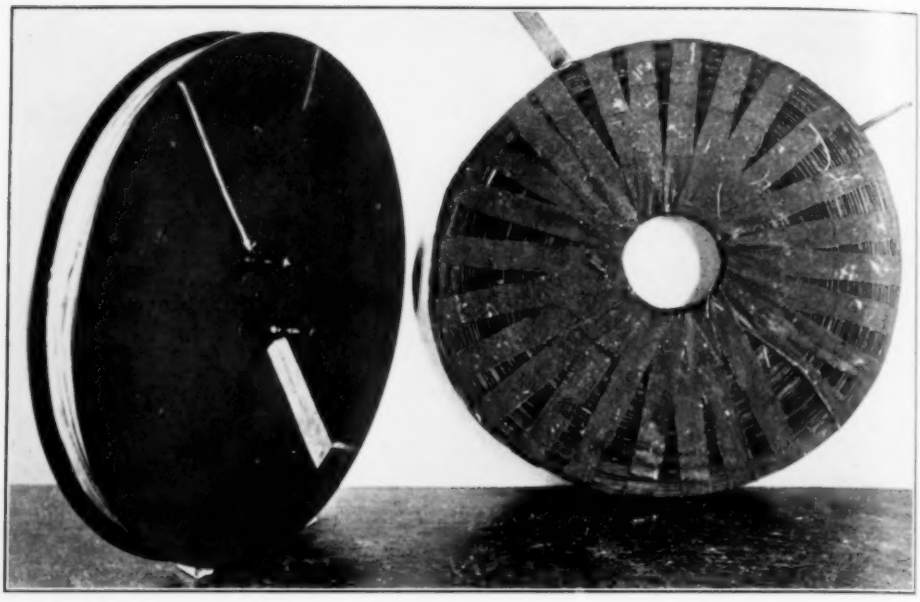
> While it appears, therefore, that Morse can not justly claim priority in the discovery of a single scientific principle involved in the telegraph, it must be admitted on all hands that he played a most important part in its development.[11]

Another experiment, performed by Henry at the academy in 1831 and said to be his greatest contribution to electricity, led to the discovery of the method of producing induced currents. This is the underlying principle of the dynamo, which as we know it is that in a closed circuit a current may be induced by any change in the lines of force of a neighboring field. Here is Henry's explanation of the principle:

> It appears that a current of electricity is produced, for an instant, in a helix of copper

[10] George B. Goode, "The Smithsonian Institution 1846–1896," 1897, p. 137.

[11] T. C. Mendenhall, "A Century of Electricity," 1892, p. 105.



APPARATUS THAT SHOWS HENRY'S PRINCIPLE OF THE DYNAMO
NOTE HOW CLOSELY THE WIRE IS WOUND ABOUT THE SPOOL.

wire surrounding a piece of soft iron whenever magnetism is induced in the iron; and a current in an opposite direction when the magnetic action ceases; also that an instantaneous current in one or the other direction accompanies every change in the magnetic intensity of the iron.[12]

He described the apparatus as follows:

A piece of copper wire, about thirty feet long and covered with elastic varnish, was closely coiled around the middle of the soft-iron armature of a galvanic magnet . . . so wound upon itself as to occupy only about one inch of the length of the armature which is seven inches in all. The armature, thus furnished with the wire, was placed in its proper position across the ends of the galvanic magnet, and there fastened so that no motion could take place. The two projecting ends of the helix were dipped into two cups of mercury, and there connected with a distant galvanometer by means of two copper wires, each about forty feet long.[13]

[12] Published by Smithsonian Institution: "Scientific Writings of Joseph Henry," Vol. I, 1886, p. 76.

[13] Published by Smithsonian Institution: "Scientific Writings of Joseph Henry," Vol. I, 1886, p. 75.

Henry then called an assistant to make and break the circuit, while he watched the needle of the galvanometer, and he was made aware of a current of electricity by the momentary deflection of the needle, first to the west as the circuit was made, then to the east as it was broken. Henry told his assistant in Albany that he had visioned this experiment one night after he had retired and that the next morning, in his small laboratory, he actually drew a spark from the magnet. The writer has seen the original apparatus used by Henry in performing this experiment; also the electric motor and the electric telegraph with the small bell attached, all of which have been preserved by the Albany Academy.

Although the results of Henry's experiment were not given out immediately, it is now generally conceded that he worked independently of Faraday, and there is every reason to believe he anticipated Faraday's work. George B. Goode says it was only through the

use of the quantity magnet perfected by Henry in 1830 that Faraday discovered magnetoelectricity.[14] Employing Henry's spool magnet to perfect his principle, Faraday concluded his experiments in 1831 and published his results at once. While Henry's discovery was earlier than that of Faraday's, he did not receive credit for it because he failed to make public his results at the time. Henry, in an outburst to one of his colleagues a little later, said: "I ought to have published earlier, but I had so little time. I desired to get out my results in good form, and how could I know that another on the other side of the Atlantic was busy with the same thing?"[14] Dr. Fleming, an English writer and scientist, is quoted as follows:

> Henry's claim to be an independent discoverer of the fundamental fact of electromagnetic induction is not now disputed. In the July number of Silliman's *American Journal of Sciences*, for 1832, Joseph Henry . . . gave an account of the manner in which he had independently and before receiving an account of Faraday's work performed in the previous autumn, elicited from his own great electromagnet an induced current by wrapping round the soft-iron armature certain coils of insulated wire. In the same paper in which he thus discloses his discovery he rendered an account of that in which he had in turn anticipated his illustrious rival by the discovery of the fact of self-induction of a spiral conductor, and denoted the phenomenon by the name by which it has since been known.[15]

While at the College of New Jersey, Henry added to the principle of the electromagnetic telegraph that of the telegraph relay, thus making telegraphy possible over a considerable distance. Using for the first time the earth as a return conductor, he set up the apparatus between his own home and the laboratory at the college. His device enabled him to open one circuit by means of another, and he successfully demonstrated that it was possible to transmit a current over a considerable distance without any great loss of power. In other words, he showed that it was possible to utilize the power of a quantity magnet through the agency of the intensity magnet. This was Henry's underlying principle of the relay.

During Henry's early years at Princeton, he began a series of experiments which resulted in producing inductive currents of different orders. These currents also had different directions, and were made up of alternate waves in opposite directions. During this series of investigations, he showed that an "induced current may excite a second induced current in a neighboring closed conductor, and this last may induce a third current in another neighboring closed circuit, etc."[16] Henry called

[14] George B. Goode, "The Smithsonian Institution 1846–1896," 1897, pp. 124 and 128.

[15] Bancroft Gherardi, "Joseph Henry's Experiments in the Albany Academy, 1827–1832," 1917, p. 11.

[16] Published by Order of Congress: "A Memorial of Joseph Henry," 1880, p. 494.

PHOTOGRAPH OF ORIGINAL BELL USED BY HENRY IN WORKING OUT HIS EXPERIMENT OF THE ELECTRIC TELEGRAPH.

THIS BELL IS PRESERVED BY THE ALBANY ACADEMY.

I remain very truly
your friend & servt
Joseph Henry

these currents of the first, second, third, fourth, and fifth orders. He further experimented by placing a piece of metal between the neighboring conductors. Immediately the induction was neutralized, because of the current present in the metal. Later he demonstrated that a current of quantity could produce a current of intensity, and *vice versa*.

Henry's next researches were in connection with ordinary or frictional electricity, by means of which he showed the effects capable of being produced at some distance. He says: "If a shock were sent through a wire on the outside of a building, electrical effects could be exhibited in a parallel wire within the buildings.[17] His investigations covered

[17] Published by Order of Congress: "A Memorial of Joseph Henry," 1880, p. 151.

induction of various kinds, such as atmospheric induction, induction from thunder clouds.

It was at Princeton also, in 1842, that Henry discovered the phenomena of wireless telegraphy, as he noted, in experimenting that the discharge of a Leyden jar through a coil of wire would induce currents in other circuits at some distance away. He noted, too, that these currents did not flow in one direction, but that they oscillated back and forth rapidly. Here is Henry's experiment:

> He passed the electric discharge through a wire round a needle. This object being of highly tempered steel retained the magnetism communicated to it by the current. Henry found that, when the needle was examined after the current had flashed around it, its north and south poles were not always at the ends which should have been produced by the discharge, but were often in the opposite direction, the north pole being the one that should have been south. He immediately saw the cause. The electricity must have flashed first in one direction and then in the opposite one. In perhaps the millionth of a second it not only destroyed the magnetism which had first been produced by the current but induced a magnetism of the opposite kind.[18]

Felix Savary, however, should receive credit for having "first advanced the hypothesis of electrical oscillations as early as 1827."[19] It was left to Helmholtz and Sir William Thomson, afterward Lord Kelvin, to experiment at greater length with regard to these oscillatory currents. Then, in 1887, Hertz proved the existence of these undulations; he measured their length and velocity, which he found to be equal to that of light, and showed that they were susceptible of reflection, refraction, and polarization. Henry, however, should receive credit for his contribution to wireless, because he demonstrated the principle of wireless in his experiment with the Leyden jar. Stated in terms of the present day, Henry showed that whenever an electromagnetic disturbance comes in contact with a conducting circuit, there is set in motion in that circuit an induced electric force which oscillates back and forth very rapidly.

Then, as stated above, Henry received a call to act as secretary of the Smithsonian Institution. According to the will of Smithson, a sum of about $650,000 was available for the founding of this American institution of learning. A short controversy over the acceptance by Congress of such a large sum from a man of English birth was speedily overcome, and the money was brought into this country to be reminted. The object of the institution, as organized in 1846, was to "promote science and the useful arts, and to establish a national museum of history."[20] In the completed building were to be housed "all objects of art and of foreign and curious research, and all objects of natural history."[20] It was left to Henry to draw up a program of organization, and in this he tried to conform to the wishes of Smithson as he interpreted the wording of the will.

Henry interpreted the phrase "to increase knowledge" to mean the discovery of new truths of any sort through research and other aids. To make this possible he proposed: (1) To stimulate men of talent to make original researches, by offering suitable rewards for memoirs containing truths; (2) To appropriate annually a portion of the income for particular researches, under the direction of suitable persons.

For the other phrase in the will, "to diffuse knowledge," he suggested the following aid: (1) To publish a series of periodical reports on the progress of different branches of knowledge; (2) To publish occasionally separate treatises on subjects of general interest.

In such ways Henry planned to use the money that it might benefit the greatest

[18] David Starr Jordan, "Leading American Men of Science," 1910, p. 128.

[19] Published by Order of Congress: "A Memorial of Joseph Henry," 1880, p. 255.

[20] *Encyclopaedia Britannica*, Vol. XXV, 1911, p. 274.

JOSEPH HENRY IN HIS EARLY THIRTIES.

numbers. It is said that some of the early members of the new institution suggested a society similar to the Royal Society of England, but Henry reasoned that this was not Smithson's intention in willing the money to an American city. Henry, it seems, had learned of a former will, whereby the Royal Society of London had been the beneficiary of the sum later willed to the city of Washington, and he concluded that Smithson had become displeased with this society for some reason and that he desired to have his money used in fields of work in some country other than England. A statement in the New International Encyclopaedia gives as his reason for making a new will that "a sense of wrong in the illegitimacy of his birth alienated him from his native land."[21]

During the thirty-two years that Henry acted as secretary of the institution, he was active along many lines. He became president of the American

[21] New International Encyclopaedia, Vol. XXI, 1916, p. 205.

JOSEPH HENRY WINDOW IN THE BIBLE SCHOOL ROOM OF THE FIRST PRESBYTERIAN CHURCH OF ALBANY.

HENRY IS DEMONSTRATING, BY MEANS OF A RUDE DYNAMO AND A BELL, THE POWER OF ELECTRIC MAGNETISM. MUCH CREDIT IS DUE MRS. JAMES F. MCELROY THROUGH WHOSE UNTIRING EFFORTS THE FUNDS FOR THIS WINDOW WERE RAISED.

Association for the Advancement of Science in 1849. In 1851, he received the degree of LL.D. from Harvard; he had received this same degree from Union College in 1829. An original member of the National Academy of Sciences, he became its president in 1868. He was also appointed to head the Lighthouse Board in 1871, and in this capacity he helped the government by tests that resulted in improving fog signals and other signal lights used by seamen. As a side issue he was instrumental in getting the government to collect and distribute meteorological information by means of the telegraph. Thus, our present-day weather bureau and weather forecasts are only the development of such service started more than half a century ago by Joseph Henry. Besides, Henry was active in cataloging scientific papers, and in this he sought the cooperation of the British Association for the Advancement of Science. In 1864, when the Royal Society issued its first "Catalogue of Scientific Papers," this tribute to Henry ap-

peared in the preface: "The present understanding may be said to have originated in a communication from Dr. Joseph Henry, Secretary of the Smithsonian Institution."[22]

Some time after he accepted the position at Washington, he was offered the presidency of the College of New Jersey, but he declined this honor because he thought he could reach more people through his work at the institution. He still maintained that his ambition was to add to the sum total of human knowledge by the discovery of new truths which might be of some use to the world; the practical application of these, however, he was willing to leave to others.[22] Like his contemporary, Faraday, Henry did not crave fame; in fact he never asked for but one position during his entire life, and that was during the time he was studying at Albany Academy. In order to earn money to go on with his work there, he sought a position as teacher in a country school district. Because of his immaturity, he was accepted on trial at a salary of $8 a month. He proved so efficient that he was asked to return for the next term at the grand salary of $15 a month. Not only in his youth, but throughout his entire life, the salary given to this man was never in proportion to his services. Mrs. Lucy E. Sanford, in an article published at the time of Henry's death, said:

> He lived on a salary that was a disgrace to the nation and ever an embarrassment to him; . . . large prices had been offered for his name to further private schemes; but he never sold it, and lived within his salary always.[23]

A short comparison of Henry and Faraday,[24] the two men who did so much for the scientific world, seems very appropriate at this point. Henry was born in 1797 and died in 1878; Faraday's dates were 1791 and 1867; each man lived beyond the threescore and ten mark and devoted practically his entire life to scientific work. The parents of both men were working people with only a small amount of education. Henry, as well as Faraday, became interested in the subject of science quite by accident. Henry read his first scientific work while he was forced to inactivity because of illness; Faraday discovered science through reading Mrs. Marcet's "Conversations on Chemistry," during his daily work in a bookbinder's shop. These two men were, to use a present-day term, self-made men; neither had a college education; of the two, Henry perhaps had the advantage, because he did attend the Albany Academy. Faraday attempted self-culture by his attendance at lectures, and as a result he secured the position of assistant in the laboratory of the Royal Institution in 1813. Henry's works and discoveries were many, although only four have been mentioned in detail in this paper—the development of the electromagnet in 1827; the principle of the electromagnetic motor in 1829; the principle of the electromagnetic telegraph in 1830; and the principle of the dynamo in 1831. Faraday's first experiments were in chemistry, but in 1821 he turned to the field of electricity. His first work in that year was in connection with the revolution of a magnetic needle around an electric current. During the next ten years he experimented unsuccessfully in an endeavor to work out the principle of the dynamo, for it was not until 1831 that he discovered the method of producing induced currents. He also discovered the action of one current upon another, and during his later years he devoted his time to researches in elec-

[22] George B. Goode, "The Smithsonian Institution 1846–1896," 1897, pp. 132 and 789.

[23] *The New York Observer:* "Professor Henry's Funeral," by Mrs. Lucy E. Sanford, May 16, 1878 (approximate date).

[24] Silvanus P. Thompson, "Michael Faraday: His Life and Works," 1898, pp. 2–299.

trolysis. Like his contemporary, Henry, he also refused fees and high honors, in order that he might devote himself to the interests of science and his fellowmen. Both these men were gentle and unassuming, but withal deliberate and persistent; and each was filled with a disinterested and lifelong devotion to scientific research.

Henry had a fascinating personality and, as the magnet with which he worked attracted things to it, so he seemed to draw people to him. Because of his simplicity, his patience, his unselfish nature, his honorable dealings with all, and his many acts of kindness among the poor, he was well received, in this country as well as in Europe. An item published in one of the New York papers shortly after his death described Henry as follows:

> In person, Professor Henry was of more than medium height, and of large and sinewy frame. The kindness of his nature was stamped upon his features and his lips ever bore a patient smile which, however, did not detract from a certain firmness of expression. His manner was gentle, suave and dignified . . . and to his friends, especially to the younger men of science, Professor Henry was always ready to give encouragement in their pursuits and to aid their efforts in opening new pathways of research.[25]

Henry believed in teaching, not by theory, but by practice and by thinking out problems. One might almost call him a true visionary, always active, always looking ahead to some new experiment, never able to decide things hurriedly, yet always persisting until he had reached some definite conclusion. Even as a youth he was very deliberate. A story that shows this habit of deliberation is told about the first pair of boots he ordered from the village bootmaker at Galway. The young man, faced with the problem of choosing between round or square toes, saw the boots slowly nearing completion without being able to come to any definite conclusion regarding the style he preferred. Imagine his surprise when one morning the bootmaker presented the finished boots to him, one modeled with a round toe, while the other stood forth in all splendor with a square toe. It is said that from this time forth Henry was more hasty in making decisions about important and weighty matters.

In religion Henry believed in theism, nor was this belief weakened by his knowledge of science. He was a scientist first and always, but he was also a Christian, a member of the Presbyterian Church and a believer in Christ the Saviour. He said that "next to the belief in his own existence was his belief in the existence of other minds like his own, and from these fixed, indisputable points, he reasoned, by analogy, to the conclusion that there was an Almighty Mind pervading the universe."[26] He was much troubled over the conflict between science and religion, but he stated that at times these two would be unintelligible, the one to the other. He said, however, that if each followed the principles of truth, there could be no conflict whatever. He further asserted: "The person who thinks that there can be any real conflict between science and religion must be very young in science or very ignorant of religion."[27]

In conclusion it can be said that, although Henry worked out principles which he left to others to apply, his name will endure for all time, as the word "henry," the standard unit of inductive resistance, is in common use to-day. Dr. Finley says of Henry:

[25] *New York Tribune:* From a scrapbook item *re* Joseph Henry, May 16, 1878 (approximate date).

[26] Published by Order of Congress: "A Memorial of Joseph Henry," 1880, p. 199.

[27] John H. Finley, "Address at Unveiling of Statue to Joseph Henry at Albany, N. Y., 1928," p. 11.

"He was in the van of the precursors of what I have often called the televictorian age—the age of the conquest of the far by telegraph and telephone, by radio and motor."[28] Henry died in May, 1878, at the age of 81. The following article appeared in the *New York Observer* in regard to his funeral:

> One by one, or at most few at a time, came and were seated: the President and Cabinet, the Supreme Court, both Houses of Congress, the Academy of Science with representatives from Yale and Harvard and other Colleges, the Diplomatic Corps, the Alumni of Princeton, the Clergy, officers of Navy and Army, the Philosophical Society of the District, District Courts, the Lighthouse Board of the Treasury, Directors of Corcoran Art Gallery, and the Examiners of Patent Office.[29]

Thus did Henry's own nation honor him and acknowledge his rank among her men of science.

[28] John H. Finley, "Address at Unveiling of Statue to Joseph Henry at Albany, N. Y., 1928," p. 15.

[29] *The New York Observer:* "Professor Henry's Funeral," by Mrs. Lucy E. Sanford, May, 1878.

THE UNITY OF NATURE AS ILLUSTRATED BY THE GRAND CANYON[1]

By Dr. JOHN C. MERRIAM
CARNEGIE INSTITUTION OF WASHINGTON

In development of science adequate study of the vast accumulation of materials makes necessary a degree of specialization which will give to each student close acquaintance with the facts bearing upon his problem. A true picture of nature can be obtained only if the investigator sees every angle of the physiognomy of each object examined. In this acquaintance there must be assurance comparable to the ability we attain in recognizing instantly our neighbors across the street, or our associates in the office. This must be true, whether we are considering sea-shells from remote areas of the world, or infinitesimal constituents of the blood, or barely attainable elements of the starry heavens. Lacking such knowledge, the judgment of science would be open to criticism as resting upon superficial observation.

But intensive specialization brings serious consequences. The student of butterflies, whose soul is plunged into ecstatic tremors by the flashing wings of a rare species, may be wholly unresponsive to stimulation by flight of the swallowtail kite which throws the ornithologist into a state of great emotional exaltation. To both entomologist and ornithologist, the intellectual joy experienced by the pathologist in distinguishing from each other two types of almost formless bacteria may be almost incomprehensible.

Not only may the characters or criteria vary in different groups of things to such an extent that the problem of one student is not appreciated by those in other fields, but each researcher tends to dig himself into so deep a hole, or to fly so high or so far, that often the greater world, with all the other little worlds in it, seems lost to sight.

The day when the "naturalist" could know the details of all subjects is past, but the necessity of seeing the larger field is not less. Many of the major advances in science come through vision of relationship among regions of research which appear widely separated, and yet are connected in a very real sense. So atomic physics of the laboratory has proved to be one of the most important tools in study of the stars. In another direction there can scarcely be a wider gap in nature than that between astrophysics and problems of biological inheritance. And yet a singularly important question is presented by possibilities of influence from cosmic rays, assumed to arise in interstellar space, upon development and variation of certain elements in the living cell.

Some of the greatest discoveries arise through association of persons engaged in study of widely separated subjects, but each sufficiently broad-minded to consider the relation of his work to that of others. Such advance depends in a measure upon experience or training in fields of breadth adequate to open a vision of the larger picture.

Appreciation of the need for considering each problem of nature in the light of its relation to the larger scheme of things may come from contact with any situation in science or in everyday life.

[1] Read on occasion of inauguration of President Shantz at University of Arizona, April 24, 1930.

It is, however, possible for us to live long without having this revelation of unity as seen through continuity in operation of natural law in time or space.

Perhaps the earliest expression of this view of unity appeared in the idea of one God in Nature, instead of many warring deities. Certainly there has been no greater stride in human thinking than that which extended to the universe the type of coherence that modern science reflects in the law of gravity, or in the marvelously rigid adherence to rules of movement in light.

But the world of thought is not a level plain. In it there are mountain peaks and valleys, and a sudden view over wide fields sometimes gives a startling vision. So with respect to interrelation of the elements of nature, there are places where the picture reveals with exceptional clearness the idea of continuity in law and interdependence of the features involved.

If one were to take the instant wings of thought and flash through the universe of space and time and movement, it is doubtful whether within the range of these wide spaces there would be found another situation presenting as much of continuity through time and action as is seen in the cinema of earth history at the Grand Canyon. There may be other places on this earth that are comparable. If so, they are few. We have no assurance that close similarity to this particular type of relationship will be discovered elsewhere in the universe. I have chosen to turn attention to this concrete thing which touches both our intellectual and our spiritual life. I look upon it as a treasure house of science—an immeasurable influence upon human thinking and ideals.

In this age of experiment we have established the idea that observation of a process is more important than speculation or calculation. The assumed laws or modes of procedure upon which we base calculation may be inexact. If so, the results will express this inadequacy. Experiment is only experience in a measure under guidance or control.

History, whether relating to man or civilization, or to the earth, or to astronomy, is a record of experience. Time and the relative position of events in it represent one way of describing the occurrences. This expression of experience indicates in some measure the laws which have governed action.

To-day the world stands at attention when the astronomer stops in his task to tell us of the history or evolution of worlds, of planetary systems, or of spiral nebulae. Also, regardless of any preconceived notions, all mankind watches with intense interest whatever comes from investigations on the history of man's long-extended striving to better his position and to deepen his knowledge.

But nowhere in the universe of stars, nor in human experience, nor in any other phase of history, do we visualize in a manner more striking than that at the Grand Canyon the presence of moving events of history, with the reality and order of occurrence so visualized that one sees, as it were, the whole panorama in action.

Astronomical measures of space and time reach to figures that we fail to comprehend. We are staggered by the statement that light moving at its terrific pace would require one hundred to two hundred millions of years for passage from some of the more remote spiral nebulae to the earth. In looking out over space, the universe as we see it in different places actually represents different geological ages perceived at the same moment. At the Grand Canyon a vastly longer series of ages, or of different times, is visualized at the same

moment and in the same place. The events in the Grand Canyon story are, moreover, presented in such manner as to express continuity of action extending through them.

Outside the field of geology, I am not aware of any actual measure of events in the universe, even remotely related to observation, which involves more than approximately two hundred million years. The story of the Grand Canyon, as seen in a casual glance, gives us, according to the geologist, a reasonable assurance of considerably more than one thousand million years.

The geologist divides his story of the earth into the astronomical period and the strictly geological. For the first he depends upon the astronomer. There is no observatorial record of this part of the past.

The strictly geological record based upon actual relics which we may examine divides itself into three parts: first, an early or Archeozoic, in which the record is heavily defaced by influences that have almost completely changed the remaining materials. No traces of life are found in this rock system.

A second period, or the Proterozoic, is represented by a vast thickness of layers formed upon the earth's surface by processes much like those in operation to-day. From these rocks, resembling mud, sand and gravel of to-day, we have rare remains of life foreshadowing that of the present.

The third division of time, approximating in length the second, includes most of the great formations we meet generally over the world—tens upon tens of thousands of feet of strata, like deposits of to-day, and containing abundant remains of plants and animals.

In a single glance at the walls of the Grand Canyon these three divisions of time are all clearly represented together.

The Archean or the oldest rocks here shown are the torn and mangled remains from an earth of so long ago that almost have the elements destroyed it. The mass was buried at times beneath so deep a load of sediment that it barely escaped complete alteration of every physical character. It was filled with materials that crept into interstices of its shattered body. It was squeezed into mountains and again lifted high till erosive forces in large part wore it away. What we have left represents time and antiquity as does perhaps nothing else that we may find in the universe.

The twelve thousand feet or more of strata of the second great series, beginning at the bottom as it does with masses of rolled pebbles, including fragments of rocks from the first or earliest division, presents a picture of conditions not materially different from those on gravel bars of the Colorado River near at hand. With all their hundreds of millions of years of antiquity, it was on an earth as of yesterday that these deposits formed.

To the casual observer, this story of time in the canyon walls may appear broken by many gaps. But what might be called interruptions are only changes of scene. Where the rolled pebbles of the second great series rest upon the oldest rocks, they are mute evidences of an uplift during which mountains were formed and washed away—perhaps the greatest single story of the region.

The relation of this seeming eternity of action in the story of the canyon to the physical processes of which it is an expression involves questions which we answer only in part. The natural forces that produced these changes are of two kinds: first, those movements of the outer earth which have lifted the continents and mountains; secondly, the

agencies which have moulded the uplifted masses into forms of the land.

Of the first element, the movements of the earth now up, now down, the canyon gives reality, though only partial explanation. But we are not ashamed to say we do not know, at any rate when gravitation, constituting an important phase of the problem, remains itself one of the greatest mysteries of nature.

More easily visualized are the forces which have moulded the land. Often as one watches from the brink of the canyon, a cloud floating by is seen to lower a dark curtain of storm. In its path rain lashes the slopes, streamlets flow in the ravines, and mud-discolored waters begin their journey to the sea. This power that carves and wears the land, spreading the debris as record of its work, involves the wind that shepherds swiftly changing clouds, and all the features of the atmosphere.

No one who sees this picture at the canyon fails to realize that as the cloud which shapes itself and vanishes, so runs the story of the land. The rocks we see are only fragments that remain from great formations of ancient time. They bridge the short span of eternity which lies immediately behind us.

It is not possible to consider the geological story excepting in terms of the physical forces involved. It is also true that the nature of these elements is in considerable measure interpreted by the way in which they have operated geologically. In a sense the two problems become one.

To what extent the sources of physical power concerned lie outside this earth is at the moment a question for discussion. Some hold that if not as a cause, at least as occasion, the effect of radiation from the sun, along with gravitational influences, may have bearing upon movements of the earth's crust. The agencies which lifted the bulk of the great plateau high above the sea may, with participation of gravity, have involved light, heat and electric activity, which also give life to the winds and clouds.

The varied features of the scene are in reality one picture, from clouds to forming of the canyon; from the veil of beauty flung over it by shifting light to the immeasurable power that raised and bent the mountains' mass. Whether it be scientist or only one who comes to glory in the work of nature, the value of every part in it is most highly dignified when seen against the background of an interlocking group of elements, each most fully interpretable when considered in its relation to the others.

The Canyon has long been a superlative spectacle without reference to any direct relation it might have to the origin or becoming of life. To-day we see it not only as a place of great physical wonders, but as presenting, embedded in its story, one of the most thrilling accounts of the adventure of life through the ages. As yet this story is largely unknown, waiting for those who will come to chart these wildernesses of the past.

The record of life begins in the lower strata of the second series, the Proterozoic. It leads on up to the highest level of the walls. Then out across the Painted Desert and into the highlands to the north the story continues in still later strata. The multitudes of animals that favored the sea left their skeletons in myriads. Creatures that came out upon the land marked prints of their fingers in numberless thousands on sands of long ago which now form a part of the canyon walls. Dinosaurs pressed their feet into the soft surface, and the traces remained until we could come and wonder. And so into these millions of years of earth building the story of life is woven.

The intertwining of these threads of coming life with those of earth evolution we do not fully understand. The relation is at the same time the greatest mystery and the greatest challenge of the region.

In the presence of such overwhelming physical features as those of the Canyon the living things of to-day that clothe the gentler slopes, or mantle the floor and the plateau above, may seem to have no greater importance than what we have known abundantly elsewhere. But they are of great significance in the larger story of the place, even if it is viewed mainly as a physical picture. In relation to study of the history of life, they express in striking manner some of the most interesting factors involved in the long record of living things entombed in the walls.

As illustrating the idea of interdependence of elements in nature, the garment of life spread over the canyon is an outstanding feature of this great spectacle.

In order that comment regarding significance of the life of the region to-day may be presented through concrete example, I have chosen to view the situation by way of a single incident. Riding through the forests of the North Rim on a recent journey to the Canyon, I saw a flash of black and white. The ranger said it was a "Kaibab squirrel, an animal peculiar to this area." In the branches of a yellow pine we saw him well—a striking figure with tasseled ears and a plump, dark body contrasted with a long white tail. His closest relative, the Abert squirrel, was said to be at home in the same type of forest on the opposite margin of the canyon. Only the gorge of the Colorado separates the areas in which they pasture. But never does either member of the family cross the gulf.

No one who sees these two closely related but strikingly different creatures, and learns that they live in areas separated only by the canyon, fails to ask how it happens that the boundaries of their range can almost touch without overlapping or mixing of the types. Is it chance that they resemble each other so nearly and are at the same time geographically so close? Did the two species migrate from distant regions to encounter this impassable barrier that prevented their knowing each that the other is there at the nearest point across the way? Or were the squirrels here before the canyon formed, or at least before it developed as a sharply separating chasm?

That two animals, each of all kinds in the world most like the other, should journey to a region where they would be separated by such a barrier is possible, but only as a remote chance. That the ancestors of these squirrels were there before the gorge took its present form, and through this separation were divided into groups that gradually came to differ, appears reasonable under certain conditions. It would seem necessary to assume relatively recent development of the canyon, and also that variation in characters comparable to what is illustrated in these types has actually taken place in the past.

In examining the story of these two species it is important to note that not alone do the "Kaibab" and "Abert" squirrels show this interesting distribution in areas separated by the canyon. Associated with them, and separated geographically in precisely the same way, are types of spruce squirrel, chipmunk, ground squirrel and porcupine, along with others.

Concerning the first assumption, touching barriers to migration, it might seem that the canyon has little significance as a bar to movement of plants and animals. Deep as it is, many lateral

extensions of the gorge give entrance to its floor. So far as means of travel are concerned, there is abundant opportunity for animals of all types and sizes to reach the lowest level and climb the opposite bank. The torrential river is a hindrance, but many creatures could find their way over it by swimming. Others would be washed across on rafts of debris in periods of flood.

But when the trained zoologist makes his census of life in the canyon according to location, he discovers that many animals competent to move freely up and down or across do not take advantage of this possibility. A map of the whole fauna and flora shows distribution corresponding largely to altitude and to physical and climatic conditions along the walls. In general, only the species of winged animals such as birds and bats extend across the gorge.

The range of climate along the canyon shows the floor to be approximately twenty degrees warmer than the South Rim. In winter, one leaves snow above to pass down through spring into summer. In summer you leave cool nights at the rim to find a zone of tropics below. Standing on the South Rim and looking into the valley of Bright Angel Creek, at the bottom of the gorge, there is seen a region of mesquite, acacia and cactus with environment of the desert. Looking across to the highest land of the North Rim, you discover an area clothed with beauty of pine, spruce and aspen forests. Each zone of altitude has its peculiar conditions of temperature and of plant and animal life.

How these belts of physical condition developed and how they came to have each its peculiar life complement are questions involved in the inquiry whether the canyon and its climatic conditions always existed as we see them to-day.

Some part of the answer as to history of the gorge appears in the fact that the strata in which the canyon is cut are in considerable part deposits such as form only on the floor of the ocean. The upper layer in the walls is composed largely of remains from sea animals. Included are corals and the teeth of sharks. The present position of this limestone, at 7,000 feet above the sea on the South Rim, ranging to 9,000 on the north side, and several thousand feet lower at the town of Kanab to the north of the Kaibab plateau, indicates an immense change of position through uplift and warping.

While this movement of the strata was taking place, or subsequent to it, the stream cut its way across the mass. The possibility of zones of physical condition developed as the region was being lifted. To-day the rocks of this area fill more than two thirds of the habitable space in the atmosphere between sea-level and the zone of an arctic climate at 10,000 to 12,000 feet elevation. These belts of climate were, so to speak, exposed by the river as it cut its way.

Whether or no the squirrels were there before the canyon was excavated, there was a time when these climatic zones, with their possibilities of varying life, had not been developed. If the squirrels had been present in the region at any level of altitude before the canyon was formed, gradually they would have found themselves separated into two groups in areas divided by barriers unfavorable to intermigration. Or if great climatic changes occurred in the course of cutting the canyon the squirrels have shifted their habitat until they are now divided by a gulf of climatic differences corresponding to the magnitude of the chasm.

The second assumption which seems a requirement, if we are to believe that present distribution and differences of the two types of squirrels are related to

physical modification of the region, concerned evidence that animals have in the past changed to the extent of difference between these species. This question we may not answer fully by evidence at the Canyon, but most suggestive data are presented.

In the same landscape which shows us such striking illustration of adjustment in present-day life associations to changing topographic and climatic conditions, we see a tremendous spectacle of life as it was modified through the geological ages. This record of the rocks presents proof of abundant life through a vast period, in which the kinds changed many times, and tended gradually to approach types living to-day. The strata in which these remains of animals and plants are buried give evidence that the physical conditions constituting the environment of life varied markedly through geological time. In a manner keeping pace with these modifications in the physical world, the living things changed also.

So in viewing the story of variation and distribution of the tree squirrels in the North Rim and South Rim areas, one comes always to the idea that the account is most logical when seen as an expression of many interrelated factors. There appear to be included the influence of physical changes which we understand only in part, and of biological laws concerning which our knowledge may be even less clearly adequate.

The more closely one studies the time panorama of the Canyon area, the more numerous are the problems raised regarding history of the relation between life of the region and its environment. Among the factors presented we can not avoid recognizing the connection between development of existing zones of life spread upon the walls and the physical changes that produced the gorge. Whether or no this relation indicates direct influence of these developing physical conditions upon the different life associations by which they are inhabited, they at least illustrate an adapting of groups of living things to physical conditions as they varied. In the same way it is difficult to understand the close relationship of species so clearly held apart by sharp geographic separation, without assuming that topographic and climatic changes are among the important factors concerned.

The present status of scientific knowledge does not afford us evidence of experimental type indicating the manner in which the suggested relation between physical environment, varying through time, and changing biological characters has developed. We are at the moment in a stage at which we know that we can not dispense with an environment, and yet do not know precisely what the influence of surrounding conditions may have been. But certain it is that no one can stand before this scene without being conscious of the fact that life as we see it in the landscape to-day mirrors the past and its changes. The unity of nature so strikingly illustrated by intimate relationship between physical factors in this story is no less clearly expressed through linking of biological features to each other, or to development of the physical world in and through which life has grown.

We have seen a picture of the Canyon as visualized by the scientist. But the deep impression which evidence of unity in operation of the forces involved makes upon the investigator may not be more important than that in the case of students of nature concerned only with what is sometimes called the human point of view.

In some respects it is difficult to distinguish the phases of thinking defined as scientific from those known as esthetic or spiritual. The stimulus which

drives a great constructive worker in science may separate itself only slightly from that influence leading the master in art or literature to what he considers his mission.

The scientist takes the impression he has received from nature as the starting point for an adventure in securing and interpreting facts. The ultimate result of his effort depends partly upon fidelity to the work of obtaining a knowledge of reality, and partly upon ideals relative to significance of the facts when brought into relation to others.

The great artist or the writer does not set for himself merely the task of describing form and feature of the thing he sees. He attempts to make clear also their meaning to him as an individual human being. In proportion to the extent to which his painting of reality is inaccurate he fails. But he fails completely if his interpretation does not present a true expression of . s influence upon him, or its meaning to human kind as typified in his personal understanding or feelings.

It has been stated that nowhere more clearly than at the Grand Canyon does evidence of interrelation in elements and unity of action impress itself upon scientist or investigator. Through such visualization of nature seen as a whole we come often to realization that, even when enlarged by the lens of knowledge, the picture indicates the presence of something beyond that vision does not fully reach. So, in various other ways, artist and writer have presented the idea that, in looking upon these great examples of unity in nature, what we see may be only the shadowy expression of things greater still, which neither eye nor mind has yet been able to define.

THE PLASTICITY OF METALS[1]

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PLASTICITY is the quality by virtue of which a substance may undergo a permanent change in shape without rupture. In many non-metallic plastic materials the flow is essentially fluid. Plastic clay, for example, consists of particles which are or may be non-plastic surrounded by a liquid. During deformation the solid particles move bodily and the liquid conforms to the new shape. The mechanism of the plastic deformation of metals is, however, quite different. Metals are crystalline and plastic flow is the result of block movement of one portion of a crystal with reference to another, the movement being along crystallographic planes. Although a number of non-metallic crystalline substances possess this characteristic to some extent, the metals are in a class by themselves in this respect.

The high plasticity of most industrial metals is perhaps more responsible than any other quality for their wide-spread use. It is an essential property in the application of many metallic products and a necessary one in all metal-working processes. Furthermore, since hardness is measured by resistance to plastic deformation, and methods or treatments designed to change hardness constitute a large part of the metal art, plasticity assumes a major rôle on the metallurgical stage.

History does not record the discovery of plasticity in metals. The discovery that cold hammering increased hardness, however, can be imagined as an unexpected but welcome surprise. When it was found that the bending of a piece of metal hardened it but straightening it again did not restore the original softness, no doubt there was another surprise. In fact, the whole history of the study has yielded one surprise after another and the end is not yet.

Three of the four usual properties determined in the tensile test pertain to plasticity; the elastic limit which represents the beginning of plastic flow, the per cent. elongation, and per cent. reduction of area. Torsion, shear, compression and beam tests also involve a measure of some form of plastic deformation. In the process of breaking a plastic metal by repeated stresses considerably below the static tensile strength, plastic deformation of all or part of the section most highly stressed not only takes place but it is intimately associated with the path of rupture.

Gradually through the centuries the major facts regarding plasticity have become known as the result of manufacturing, using and testing metals and alloys. Certain treatments were found to affect the working qualities favorably and certain other treatments were found to affect favorably the utility. Prior to the advent of the microscope, much dependability was attached to the appearance of the fracture or "grain." A fine grain was needed for most industrial purposes. Fine-grained metal could be drawn into wire with less breakage and a higher degree of roundness than coarse-grained wire. High

[1] The substance of this paper was presented before Section M—Engineering, American Association for the Advancement of Science, at Cleveland, Ohio, December 31, 1930.

temperature favored ease of working but tended to produce a coarse grain. This led to low finishing temperatures. Some metals or alloys were found to be brittle at high temperatures and some more brittle at low temperatures. The practice early developed of trying a number of working temperatures for the purpose of ascertaining the most suitable range. It was learned that hot working could be carried on without hardening or without exhausting plasticity, but that cold working, especially the higher melting point metals, resulted in hardening and substantial exhaustion of plasticity. It was also learned that reheating such cold-worked metal would restore softness and plasticity.

About fifty years ago there began a new epoch in these studies. The microscope came into use as a powerful tool with which to study structures, and physical measurements were undertaken with sufficient precision to learn something of the minor changes accompanying plastic deformation. It was soon found that hot work did not permanently elongate the existing grains but that cold work did. Severe cold work would even elongate the original equiaxed grains into fibers, and reheating to anneal or soften was accompanied by a recrystallization and formation of new equi-axed grains at a temperature far below the melting point of the metal.

About 1886, Bauschinger showed that a metal cold-deformed in one direction had its elastic limit increased with reference to further extension in the same direction but decreased with reference to a load applied in the opposite direction. This phenomenon is still a subject for study and experimentation. Soon after this, Howe showed that rest and moderate heating intensified the strengthening effects of cold work on iron and mild steel, and Muir, in 1900, described these and additional phenomena, now referred to as "over strain." He showed, among other things, that iron immediately after being plastically deformed at room temperature is practically inelastic no matter in which direction the stress is applied. This phenomenon is now thought to be associated with the presence of nitrogen in the iron or steel.

Prior to 1899, mineralogists had studied the deformation of single crystals of non-metallic substances, like calcite, by "gliding," and Mugge, in 1895, had observed similar movements in bismuth and antimony crystals. It remained, however, for Sir J. A. Ewing and Walter Rosenhain, in the Bakerian lecture before the Royal Society, in May, 1899, to put the slip mechanism in metals on a firm foundation.

During the past thirty years there has been great activity in various parts of the world in the further study of plasticity. During the first twenty years of this period the studies were largely carried out with polycrystalline metals, and the x-ray was for the greater part of the period not available as a tool to assist with the interpretation of results. The studies were characterized by the ingenious use of the microscope and the use of almost every available physical and chemical test. During the last ten years methods for the preparation of single crystals of various metals of sufficient size and proper shape for tensile tests and the use of x-ray crystals analysis have enormously stimulated the further study of the mechanism of plastic deformation. The publications have been so numerous and so extensive that no attempt can be made here to give the references. A fairly complete list will be found for the past twenty years or more in the *Journal of the Institute of Metals*. A recent résumé of the literature on translation gliding in crystals

has been prepared by Buerger and was published in the February, 1930, number of the *American Mineralogist*.

Nearly all commercial metals are polycrystalline. Variation in grain size is a most important factor in connection with plasticity. Grain shape and grain orientation are also important factors. It would seem that these variations would have been sufficient to baffle the metal workers of the past, but of necessity they had to cope with the added difficulties resulting from alloying. The scientific studies of plasticity are so involved that I shall confine this discussion largely to single-phase metals.

Between 1900 and 1910 some additional discoveries demonstrating the subtle nature of the laws of plasticity were reported. Hadfield tested steels which were ductile at ordinary temperatures and found them brittle in liquid air. Beilby exhausted the capacity for elongation on tensile test of gold, copper and silver by wire drawing and then found that all the wires so produced had over 10 per cent. elongation when tested in liquid air. Hadfield's and Beilby's results seemed inconsistent with each other, but the facts have been subsequently demonstrated beyond a doubt. It may be mentioned here that fine-grained iron or sorbitic steel retains useful ductility in liquid air, but coarse-grained iron or steel becomes brittle at −190° C. It was in connection with these studies that Beilby proposed the amorphous metal theory. He held that amorphous metal harder than crystalline metal was generated on slip planes as the result of slip movement. This theory in the original form has been found to be quite untenable.

During the same decade, tungsten, which was a notoriously brittle metal, was ductilized at the General Electric Research Laboratory. In its ductile state the original grains had been elongated into fibers, the condition for exhaustion of ductility in ordinary metals. To make the anomaly complete, when a fibrous tungsten wire was heated so as to produce equi-axed grains the room temperature ductility disappeared. Here was a metal which did not obey the rules, and its more thorough study resulted in some new rules.

Toward the end of the next decade (1910–1920) commercial experience had established the fact that fine-grained sheet metal could be deep drawn more satisfactorily than coarse-grained material. Similar observations had been made with reference to wire drawing. The results had even assumed approximately quantitative aspects—the larger the grains the less satisfactory the material. The conclusion was drawn that fine-grained metal was more ductile than coarse-grained. This conclusion was not only borne out in processing, but the per cent. elongation and reduction of area on tensile tests also, in general, led to this belief. Coarse-grained zinc was, for example, quite brittle at room temperature, whereas fine-grained zinc was ductile. By extrapolation it might have been expected that a piece of zinc composed of a single crystal would be very brittle.

Imagine the surprise to find by actual test higher elongations and reductions of area in single crystals of zinc than had ever been obtained with even fine-grained metal. The directional properties of crystals had been known for many years, but these results served to rate their importance in a new light. In certain directions, with reference to the orientation of the crystal axes, the capacity for extension is enormous, but in other directions it is practically zero. It is clear now that fine-grained zinc gives a sort of statistical average capacity for extension in all directions and in all parts of the specimen. This makes

possible controlled deformation as to shape and direction, and hence fine-grained metal meets commercial requirements. Consider, on the other hand, a wire of zinc composed of grains so large that each one comprises a substantial portion of the cross-section. When wire drawing is attempted the first grain encountered which is unfavorably oriented for plastic deformation in a direction parallel with the length may cause rupture. Thus coarse-grained structures accentuate directional properties and non-homogeneity and fine-grained structures, for all practical purposes, eliminate directional characteristics of the piece of metal taken as a unit.

The study of the plastic deformation of single crystals of various metals and x-ray crystal analysis have greatly enriched our knowledge during the last fifteen years. Hull pointed out that most of the pure metals crystallize with simple space lattices. Face-centered cubic, body-centered cubic and hexagonal lattices are most common. The face-centered cubic lattice represents the most favorable arrangement of atoms for slip movement and the most favorable families of planes are those of greatest atomic density, namely, the [111] and [100] planes. In the body-centered cubic lattice, the [110] planes should be most favorable for slip. There has been some question as to whether the [110] or the [112] planes in iron, as an example of body-centered cubic lattice, are the planes on which slip actually takes place. Most of the results are consistent with the idea that slip is usually on the [110] planes and at times conjugate [110] planes may cooperate to produce slip which appears to be on [112] planes. This point is, however, too involved to expound in the present discussion. In the hexagonal system the basal plane, that is, the base of the unit hexagon, is usually the one most readily permitting slip.

Not only does slip prefer certain families of planes, but there are also preferred directions of slip along any plane. The planes and directions can be deduced with surprising accuracy by considering the atoms as solid spheres. The preferred directions correspond to the V grooves in a layer of tightly packed spheres.

Now comes another surprise. If the grains of a fine-grained metal are at the outset randomly oriented, continued working in one direction, as by strip rolling, will tend to change the fragments resulting from slip toward the same orientation. This is referred to as "preferred orientation." Different methods of working yield different results as regards preferred orientation. Still another complication arises in some metals which form mechanical twins during the course of plastic deformation. Mathewson has greatly enlightened us on this subject, his main contribution being "Twinning in Metals," published by the American Institute of Mining and Metallurgical Engineers, Institute of Metals Division, 1928. One interesting observation with respect to twinning is that most of the actual deformation takes place by slip movement the same as in metals which form no twins. The twinning is helpful in changing the orientation of the crystals in such a manner as to facilitate slip. Also, twinning has an important influence on the orientation of the grains after recrystallization. Mathewson, in coarse-grained zinc which had been alternately worked and recrystallized, has been able to find, by x-ray analysis, the "generations" of twins corresponding to each cycle.

Inasmuch as most commercial metal-working operations effect considerable elongation in one direction, preferred

orientation is common in industrial wrought metals. It is not suggested that preferred orientation impairs the utility, but it seems clear that for some purposes it is not desirable. On the other hand, preferred orientation in drawn tungsten wire seems to be a decided advantage in controlling the orientation of the recrystallized grains in lamp filaments. Iron and steel have enjoyed a sort of fortuitous immunity from either the good or bad effects of preferred orientation, at least with respect to many commercial products, like structural steel and rails. Working is carried on above the upper critical temperature while the iron is in the gamma, or face-centered cubic phase. Preferred orientation of the gamma grains no doubt obtains, but on cooling through the critical range the gamma iron changes to alpha or body-centered cubic iron and new grains form with approximately random orientation. Alpha iron which has been extensively worked below the critical temperature also develops preferred orientation. This is eliminated by annealing above the critical temperature. With the advent of the nickel stainless steels which retain the gamma phase at both high and low temperatures and silicon transformer steel as well as certain high chromium rustless irons which retain the body-centered cubic structure, hot and cold, the steel-working art faces a problem in orientation control. The same problem exists in the working of non-ferrous metals. Whether preferred orientation of grain fragments resulting from plastic deformation is desirable or otherwise, it is clear that it must for special purposes, at least, be put under control.

Surprises were also plentiful in connection with the types of fractures resulting from tensile tests of single crystals. The wedge fracture is a typical one in metals crystallizing in the cubic system. The orientation must be proper and two sets of intersecting slip planes of the same family cooperate to form the wedge. In one direction there is practically 100 per cent. reduction of diameter, and 90 degrees from this direction the diameter remains substantially unchanged. Other orientations give rise to a great variety of interesting fractures. In hexagonal metals there is a tendency for an original round section to flatten first into an elliptical cross-section and if elongation prior to rupture is considerable the final shape resembles a flat strip having a width approximately equal to the original diameter of the test piece. Again there may be an abrupt change in the shape of the cross-section as the result of mechanical twinning.

The extent of movement on a slip plane may be anything from a small fraction of an atom diameter up to more than 5,000-atom diameters. The smaller movements may only be detectable by some change in property, but the larger slips can readily be seen with a microscope. If a section of the metal is polished before deformation, the slip movement may produce a difference in level between the portions of the crystal on either side, thus facilitating detection with the microscope. Slip in many plastic metals has been studied in this manner. In some cases the slip lines are very straight and in others irregular. Some crystals show one predominating direction of movement and others exhibit sets of intersecting slips. Particularly in single crystal wires there is a tendency for the visible slip planes or slip bands, as they are called, to be evenly spaced. Some observers have reported that the spacing tends to be farther apart the higher the temperature of test for any given metal. The deformation does not proceed in a continuous manner but actually takes place

in steps or jumps. Some single crystals and coarse-grained metals give out sound, known as a "cry," during deformation. This seems to be associated with the formation of mechanical twins. This suggests an internal shock when certain of the atoms make the slight shift necessary for twinning. Apparently external shock favors mechanical twinning because alpha iron which forms no twins on slow loading will do so on impact. Another surprise may be noted in this connection. Rosenhain found that if a piece of alpha iron is deformed, even a small amount by slow loading, and if then the deformation is continued by impact, no mechanical twins form.

Perhaps some of the greatest surprises in the study of the plasticity of single crystals of metals have been the unexpectedly small loads required to permanently deform them. It is not difficult to cold-draw copper wire until it has a tensile strength above 50,000 pounds per square inch. In this condition there may be very little permanent extension in bringing the load up to this value. A single crystal of copper, however, three quarters of an inch in diameter and long enough for a grip, can be bent without difficulty in the two hands. Hardening accompanying this deformation can be easily detected because greater force is required to straighten than to make the original bend, and a second bending is still more difficult.

It may be of interest to mention that tungsten filaments approaching single crystal structure are in general use because of their non-sag characteristics. At the relatively high operating temperature fine-grained filaments sag gradually as a result of their own weight. This general phenomenon referred to as "creep" is the subject of much study at the present time in connection with metals and alloys for use at elevated temperatures. In fine-grained tungsten filaments the gradual sagging has been traced to a sort of fluid flow at grain boundaries. The grain boundaries behave as if they were amorphous. Naturally a grain boundary displacement will force some kind of readjustment on the crystals themselves, and this may take the form of slip or transfer of atoms from one grain to another.

The rate of loading is an important factor in determining the extent and nature of plastic deformation in hot metals. Coarse-grained tungsten will resist sagging for hundreds of hours but will deform if the lamp is bumped. A fine-grained filament which sags badly in the course of time will resist deformation by bumping. These factors are now very well understood, and the structure of filaments and methods of mounting are controlled to provide resistance against both slow and rapid loading.

Studies of tungsten filaments have provided some useful information. It was observed years ago that hairpin-shaped filaments mounted horizontally had about equal resistance to permanent deformation at 1,350° C. no matter whether coarse- or fine-grained. Above this temperature the coarse-grained metal was superior and below it the fine-grained metal was best. The change in the sag resistance of single crystal tungsten was not great with increase in temperature. A filament which would not sag at 2,000° C. would not sag at, say, 2,500° C. In fact, the single crystal seemed to retain a definite but small elastic limit nearly up to the melting point. There seemed to be little change in the elastic limit down to, say, 1,600° C. We observe here the same characteristic as that just described in single crystal copper. It is not conceivable that the single crystal of

copper which had an elastic limit approaching zero at room temperature could have had an appreciably lower elastic limit at say, 1,000° C., or some 80 degrees below its melting point. This same characteristic has now been observed in several other metals.

Realizing the extreme softness of single crystals of metals and the very slight change in hardness with change in temperature (at least within certain temperature limits) it now seems remarkable that the mere aggregation of differently oriented single crystals can result in the properties of poly-crystalline metals. The change in orientation alone does not seem adequate to account for all the results. Fine-grained metals not only possess markedly greater elastic limits and tensile strengths than the constituent crystals, but the properties vary with change of temperature in a different manner. For example, Sykes found that a molybdenum wire composed of a series of single crystals had the same tensile strength (30,000 pounds per square inch) in the temperature range 100 to 900° C., whereas a fine-grained molybdenum wire had its strength reduced from 115,000 pounds per square inch when tested at 100° C. to 70,000 pounds per square inch at 900° C. This discrepancy is still greater in molybdenum which has been worked below its recrystallization temperature and which in many respects simulates a very fine-grained condition.

The grain boundary effect is by no means confined to the boundaries themselves. This is illustrated nicely in Sykes' experiments in molybdenum wires, consisting of a series of crystals, each of which occupied the whole cross-section for a short distance. During the tensile test the grain boundary portions remained undeformed and the crystals necked down, the greatest reduction of area being nearly half-way between grain boundaries. This result is explainable on the ground that a change of orientation at the grain boundaries militates against the continuity of slip movement from one grain to another, but this simple interpretation does not negative the fact that fracture takes place as far from the grain boundary as it can, even though the distance be hundreds of thousands of atom diameters.

Another observation on single crystals of tungsten and molybdenum is that the elastic limit, which, as has been mentioned above, does not change much from the melting point down to relatively low temperatures, rises very rapidly on reaching a certain low temperature. A single crystal of tungsten can be bent at room temperature, but in liquid air the elastic limit is enormously increased and fracture occurs without any noticeable permanent deformation. Similarly, coarse-grained molybdenum more than trebles its tensile strength and the elastic limit is increased to an even greater extent on cooling from 100 to –190° C.

The more we study plasticity in metals the more wonderful does its nature appear. Hull attributed the brittle nature of crystals of non-metallic materials to the ionic nature of the atoms. In sodium chloride, for example, the sodium is supposed to be present as positive and chlorine as negative ions. On slipping one atom diameter positive ions are brought opposite other positive ions and negative ions opposite other negative ions with resultant repulsive forces and cleavage. There are supposed to be no, or very few, free electrons in non-metallic substances. Metals are supposed to contain free electrons. How many free electrons, what their positions or movements are or in what manner, if any, they contribute to plasticity are questions which

are as yet unanswered. Physicists are doing a large amount of work in an effort to explain metallic conduction of electricity. Any progress which they make will prove helpful in the interpretation of plasticity. So far two extremes of electron arrangement have been proposed. The so-called classical theory assumes the free electrons present as a perfect gas and Lindeman has suggested the presence of free electrons at space lattice points different from the atom lattice points. The electron space lattice is supposed to be related to the atom space lattice. Also the idea that electrons simulate waves is being considered to explain metallic conductivity. Any of these conceptions can be used to account for the very low elastic limits of single crystals if we assume that the free electrons expand the atom space lattice.

Let us digress a moment to consider this point in more detail. Although high electric conductivity and high crystal plasticity are the common attributes of metals, it is clear that the two properties do not vary in the same way and not necessarily in the same direction. It may be more than a coincidence that the best conductors of electricity have face-centered cubic crystals, which is also the most plastic type of crystal. A single crystal of tungsten has higher electric conductivity in liquid air than at room temperature but has completely lost its plasticity at the lower temperature. Intermetallic compounds are good electrical conductors, but they may be non-plastic. Also, single crystals of intermetallic compounds may exhibit an extreme resistance to slip movement. Tungsten carbide, for example, is as hard as emery. Such facts would lead us to suppose that there is little relation between free electrons and plasticity.

The noble gas, argon, solidifies at −188° C. with a face-centered cubic space lattice. It is monatomic and the atoms should not be present in the space lattice as ions. It is transparent and practically a non-conductor of electricity. It would thus appear to have all the requirements for high plasticity, unless free electrons are important. A few years ago I tested solid crystalline argon for plasticity and found it to be brittle. It behaves like most non-metallic crystals. While this does not prove that free electrons are essential for metallic plasticity, it, to my mind, strongly suggests some relationship.

Whether we like a mechanistic conception of atoms or not, they seem to behave in plastic deformation as if they are somewhat like solid spheres or similar shapes. May we not suppose that the atoms of argon in its crystal are so close together that slip movement can not take place without increasing the distance between planes? In other words, the high spots of the atoms on one plane so closely fit the recessions in groups of atoms of adjoining planes that slip is prevented. If we assume that free electrons in a metal are provided by neutral atoms, some or all of the atoms, depending on the number of free electrons, must be positively charged. This would provide one force tending to hold the atoms apart. The normal place for a free electron with its negative charge would be as far away as possible from other free electrons and between positively charged atoms. There is thus some reason to expect free electrons to increase the distances between atomic planes and there is reason to expect such increase to account not only for the great plasticity of metals but also for some of the peculiar observations with reference to temperature effects.

Taking single crystals of tungsten as an illustration, we can visualize the

important potential slip planes so far apart just below the melting point that the atoms on one plane do not engage those on adjacent planes with consequent low resistance to slip. As contraction occurs on cooling, a temperature is finally reached at which the atoms approach the condition described for argon and, plastically, the crystal behaves much like argon. Of course the high attractive forces resulting in a high melting point must have a potent influence on the low temperature resistance to deformation and rupture. This is only one of many factors, however, which will require evaluation for the clarification of this subject.

The type of space lattice is apparently very important. Face-centered cubic metals, as, for example, gold, silver, copper, lead and aluminum, retain plasticity at very low temperatures, that is, below –190° C. Face-centered cubic iron retains plasticity at low temperatures better than body-centered cubic iron. In general, the body-centered cubic metals do not retain low temperature plasticity as well as face-centered metals. Hexagonal rhombohedral metals like bismuth and antimony become brittle at temperatures not far below their freezing points. I tested fine-grained and coarse-grained commercial wrought zinc in liquid air a few years ago and found no plasticity. I concluded that the hexagonal space lattice was not conducive to retention of plasticity at low temperatures. In attempting to gain additional evidence on this point, I tested a piece of commercial magnesium wire and was rewarded with another surprise to find it quite bendable at –190° C. Mankind may have cause to rejoice in the future because the two metals, aluminum and magnesium, which have most favorable densities for aircraft use, can endure the low temperatures encountered at high altitudes without becoming brittle.

It might now be concluded that the light weight atoms have some claim to superiority in the maintenance of low temperature plasticity. To spoil this idea as having any claim to generality, it is now found that beryllium, having a lighter atom than magnesium, becomes substantially non-plastic well above room temperature.

I wish now to describe my last two surprises. Dr. Schmid, of Germany, about two months ago gave us some single crystals of pure magnesium in wire form. Each crystal was about six inches long and three thirty-seconds inch in diameter. The first surprise was in learning of the minute effort required to bend one of these specimens. The elastic limit is so low as to be hardly measurable. By holding one end of a specimen a bend can easily be made by a gentle flip of the wrist. I was not prepared to find such a soft state in magnesium, notwithstanding experience with single crystals of many other metals. My last surprise came a few days ago when one of these magnesium single crystals was cooled to –190° C. in liquid air. It remained so soft that it could be bent with scarcely any effort. The elastic limit was so low that no substantial difference between the –190° C. and room temperature values could be detected without fine measuring instruments. I hope that this material will be tested for plasticity in liquid hydrogen, and if found to be plastic at that temperature it should be tested in liquid helium.

In closing, I wish to urge upon physicists the potentiality of the study of plastic deformation in metals as a means of unlocking some doorways to nature's secrets of the internal structure and properties of solids.

UNSETTLED QUESTIONS CONCERNING THE MATHEMATICS OF CHINA

By Professor DAVID EUGENE SMITH

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SINCE it is impossible within the reasonable limits of a paper of this kind to give a detailed survey of a subject so broad as mathematics, in a country so extensive as China, and throughout a period measured by more than forty centuries, it is necessary to set up rather definite limitations to be observed. These limitations are further conditioned by the fact that I write not as a sinologue but from the standpoint of a historian of mathematics in general. These circumstances are, I take it, by no means entirely unfortunate, since they impose upon me the duty of eliminating a large amount of information which can easily be found in printed articles and books in European languages, and afford the opportunity of calling attention to a few of those subjects relating to mathematics in China which require such investigation as only a thoroughly trained sinologue with a fair knowledge of mathematics and astronomy should undertake.

In the first place it should be said that the mathematics of the Orient in general has been concerned chiefly with puzzle problems which usually present but little difficulty when solved by modern algebra, these problems more often relating to mensuration or the calendar than to commercial practice. They rarely if ever touch upon the field of geometry as considered by the Greeks, and their theory of numbers is ordinarily very primitive. Trigonometry was developed to a considerable extent by the Arabs, to a slight degree by the Hindus, and apparently not at all, as independent of foreign influence, by the Chinese. As to developing any great mathematical theory, such as Euclidean geometry, a systematic study of conics, the theory of numbers (say of primes, perfect numbers, amicable numbers, or properties of numbers), the theory of algebraic equations, analytic geometry or the calculus, China never made even a beginning that is at all worth considering. She showed marvelous patience in detail, in attaining results with crude implements, and in constructing puzzle problems of no practical value, and in all this she was inspired by a pure love for a subject which was, for her, practical only to a slight degree. Until Western influence became apparent, her mathematics existed only in the age of childhood—not that children could solve the intricate problems she often set, but that the problems were childish in content, appealing solely to the puzzle instinct of the race.

While the native mathematics of China was thus immature in content, the early histories were equally so, and this is what makes the history of mathematics in that country difficult to write. History and mathematics alike were looked upon as means of entertainment, not as branches of knowledge scientifically conceived and constructed. If the modern historian seeks for aid in the "Shu Ching" ("Canon of History"), which tradition has asserted to be the oldest Chinese historical treatise available, he finds that the work is in part a late forgery and that it contains no information before the second millennium B. C. that is worthy of acceptance. Nor is this merely the dictum of modern historians, for already about the close of the Ming Dynasty (1368–1643) Huang

Tsung-hsi (1609–1695) wrote concerning the same work that it "is shown to be spurious by its unsound chronology, by its misunderstanding of ancient rites, geographical data, penal, governmental and religious practices, and its faulty use of words and sentences as we understand these from authentic records of antiquity."[1]

Even more scientific is the critical study made by Yen Jo-chü (1636–1704), the net result of whose investigations was to

> . . . clear the way for that splendid literary renaissance which flourished in the higher intellectual circles of China in the seventeenth and eighteenth centuries and is now known to us as the period of "Han learning"—so called because its proponents went back to the original Han texts and so revolted from the Sung interpretations upon which the current philosophy was based. Hereafter, not only the classic of history, but every one of the canonical books was brought within the scope of scientific inquiry. "There should be no data in ancient history," said Yen Jo-chü, "which are not subject to investigation."[2]

The opportunity for altering Chinese texts is seen to be particularly favorable when we consider this statement of Dr. Hu Shih:[3]

> Only a half dozen systematically written books have appeared in the last 2,000 years [in China]. Works of Chinese scholars are chiefly *Chi*, that is, collections; or *Tsa Chih*, that is, notes or fragments. . . . Scholars worked in patient devotion on minute minor points, without creative imagination to see wider relationship and discover new and more significant connections.

Modern skepticism concerning ancient texts is stimulated by the works of the late K'ang Yu-wei,[4] who asserted that all the texts which were claimed to have been found in the walls of the house of Confucius were spurious, and whose "more sober judgments have stood the test of time and form the basis of some of the best sinological scholarship of our day."[5]

The effect of such studies has been to reopen the entire question of the authenticity of ancient texts, and it is in this movement that we may hopefully look for aid in the next few years in determining which claims in the field of mathematics are valid, and which are not.

This being the attitude of Chinese scholars themselves, we are justified in seriously doubting, and indeed in denying, the validity of such assertions as that the emperor Fu Hsi invented the *pa kua* (the mystic trigrams still used in divination and seen in all parts of China) in the third millennium B. C. Equally doubtful is the tradition that, in the reign of his grandson Huang Ti ("The Yellow Emperor"), perhaps in the twenty-seventh century B. C., Tai-nao devised a sexagesimal system and Li-shu invented arithmetic and wrote the "Chiu-chang" ("Nine Sections") from which the later classic, "Chiu-chang Suan-shu" ("Arithmetic in Nine Sections"), developed. Still in the realm of tradition are the reigns of his successors, Yao, Shun and Yu, and the story relating to the sentence of death passed by Yao on the two astronomers Hsi and Ho for their failure to perform the ancient rites at an eclipse of the sun.[6] The tradition that in the reign of Yu there appeared to the emperor a

[1] From a contribution by Dr. A. W. Hummel, in the Report of the Librarian of Congress for 1928, Washington, 1929, p. 304.

[2] *Ibid.*

[3] Lecture on Sinological Research at the Present Time, delivered at Peking (Peiping) before the North China Union Language School, June 12, 1925.

[4] "Hsin Hsüeh Wei Ching K'ao" ("The Forged Classics of the Wang-Mang Period"), 1891; "K'ung-tzu Kai Chih K'ao" ("Confucius as a Reformer"), 1867.

[5] Hummel, *loc. cit.*

[6] A partial eclipse was visible in North China in 2136, as modern computations show. This may serve to fix the date of Yao's reign.

divine tortoise upon the back of which there were found the *lo-shu* (the 9-called magic square) and the *ho-t'u* (another number arrangement used in divination) illustrates even more clearly the uncertainty that exists concerning all the ancient claims, for Hu Wei (1633–1714), a critical scholar, proved conclusively[7] that these diagrams (although not the names) originated with a certain Taoist priest named Ch'en T'uan who died in 989 A. D.[8] Thus a Chinese diagram, long supposed to be one of the earliest known in the field of numbers, is less than a thousand years old.

Coming down to the historical period, the early writers stated that in the Chou Dynasty (1122–249 B. C.) Wên Wang, one of the rulers of the principality of Chou, while imprisoned by the cruel prince Chou Hsin for political reasons, wrote the great classic, "I-Ching" (I-king, "Book of Changes"), this being based upon the *pa-kua* and containing this diagram and the diagrams *lo-shu* and *ho-t'u*. As above stated, however, these last two diagrams are not earlier than the tenth century A. D. As to the book itself, there is no mathematical reason for believing that the *pa-kua* is not ancient. While the diagram contains the permutations of two things taken three at a time (repetitions allowed), this is simply a matter of arrangement easily worked out by a few rods, and does not necessarily require any mathematical reasoning. As to the *lo-shu* and *ho-t'u*, although the diagrams are relatively modern, there is also no reason why a description of them or even the diagrams themselves should not have been worked out three thousand years ago, there being no serious mathematics involved.

Without further multiplying the evidences as to the unreliability of the mathematical texts as set forth by Chinese scholars, it may be added that similar doubts have been expressed by such western historians as VanHee, Vacca and Loria, and by Sédillot, who, nearly a century ago,[9] spoke of the inextricable confusion in the texts sent to Europe by the early missionaries.[10]

Equally critical of the texts is our leading historian of eastern Asiatic mathematics, the Japanese scholar Yoshio Mikami,[11] who confesses that, as regards China, "we are utterly at a loss when we try to investigate the growth of the science in remote antiquity, for old documents or records are entirely wanting."

The question of our debt to ancient and medieval China, in the field of mathematics, therefore resolves itself largely into that of textual criticism and of finding more source material. We have relatively little trouble with European texts, for scholars can usually detect at once any interpolations of consequence, either from the handwriting or from linguistic changes. It is interesting to know that the Chinese are already carrying on the work so well begun in the seventeenth and eighteenth centuries by scholars like Huang Tsung-

[7] In his "I T'u Ming Pien" ("Exposition of the Diagrams in the Classic of Changes"), published in 1706.

[8] Report cited, p. 305.

[9] "Matériaux pour servir à l'histoire comparée des sciences mathèmatiques chez les Grecs et les Orientaux," Paris, Vol. I, 1845; Vol. II (consecutively paged), 1849, p. 564. His printed works on oriental mathematics began with the date 1834.

[10] Il semble que les missionnaires européen, curieux de nous les faire connaître, et sans examen tous les récits qui rantraient, à quelque titre que ce fût, dans le domaine de la science. Aussi résulte-t-il de cette absence complète de méthode, un pèle-mêle inextricable de notions plus ou moins obscures, et de faits contradictoires."

[11] "The Development of Mathematics in China and Japan," Leipzig, 1913. Pages 1-155 are devoted to China. A list of texts, including most of those needing investigation, was published in 1885, edited Ch'en Wei-ki. For a translation and comments by Père VanHee, S. J., see *Amer. Math. Monthly*, Vol. 33, p. 502.

hsi and Yen Jo-chü, and that we may hope for authentic texts, in due time, of the mathematical treatises of the past or of the fragments that exist. The outlook is encouraging for such work on the part of Western sinologues, as witness the critical studies of Confucian texts now being made by Dr. Arthur W. Hummel, of the Library of Congress.

Having stated the difficulties, and the hope which the future offers that the chief ones may be removed through textual criticism, I wish to mention a few of the problems about which historians of mathematics need special assistance. Laying aside the questions relating to the I-ching as mathematically of little importance, I begin with the first of the classics in this field.

Is it not possible to date more precisely the "Chou-pei Suan-ching" ("Chou-pei arithmetical classic") and the various interpolations and additions of which we have evidence? The book is known to us only through commentaries of uncertain date, one of which is not earlier than the second century A. D., although the well-known dialogue which it contains seems to be of the twelfth century B. C. Since this work is said to have contained the 3–4–5 relation of the right triangle, with geometric diagrams, although no general statement of the Pythagorean theorem, it is important to know the validity of such a reference some six centuries before Pythagoras lived. Evidently that part of the dialogue which relates to the sun's orbit at the winter equinox, and which shows the use of 3 for π, is a late interpolation, but about how late? It makes mention of Lü-Shih (Lü Pu-i), a minister in the reign of Ch'in (third century B. C.), and asserts that he gave the year as $365\frac{1}{4}$ days and that the circle had $365\frac{1}{4}$ parts (degrees). If authentic, these statements have a bearing not only upon the history of the calendar but upon the relation of 360 degrees in a circle to the number of days in the ancient year, which seems doubtful.

Similarly, we need a critical study of the second great mathematical classic of China, the "Chiu-chang Suan-shu" ("Arithmetic in Nine Sections"). While it seems fairly certain that this was first written before the "burning of the books" by order of the powerful despot Shih Huang Ti ("The First Emperor"), who ascended the throne in 246 B. C., and in whose reign the Great Wall was completed, the original form of the text seems to have been lost rather through the efforts of commentators or copyists than through the failure to preserve copies from destruction by the emperor's edict. Our present knowledge of the work comes largely from Chang T'sang (*c.* 250–152 B. C.) and from Ching Ch'ou-ch'ang, who further revised it *c.* 50 B. C. In particular we should like to know whether the text is properly interpreted as stating that counters (probably rods but not the modern *suan pan*) were used by the original writer, and that he employed a method of solving three linear equations which involves essentially the simplification of a determinant by the subtraction of columns and their multiples, and hence the use of negative numbers. Mathematically considered, this latter feature in the solution is doubtful, whereas the former one is probable. The work contains the Rule of False Position (*the Regula falsae positionis* of the medieval European writers), and this too may possibly be genuine in a work of the first millennium B. C., since the Egyptians had long been familiar with the general idea; but proof of its authenticity is none the less important. It may also be observed that certain of its problems are such as are found in India in the seventh century A. D., raising the question of the reliability of the text and illustrating the interchange of ideas among races and regions.

The next mathematical treatise of importance, the "Sun-Tsŭ Suan-ching" ("The Arithmetical Classic of Sun-Tsŭ"), was formerly assigned to the sixth century B. C., which would have been very early for certain of its mathematical features. The learned Tai Cheng (1722–1777), however, showed[12] that the language used rendered it impossible that it should have been written before the reign of Ming-Ti (58–75 A. D.). What needs further investigation, however, is Sun Tsŭ's method of solving simultaneous linear equations and his work in indeterminate equations, or in problems which we would now solve by these means. Viewed from the standpoint of the history of mathematics, each of these is doubtful, although each is possible. Aside from these features the work contains little that is not found in the "Arithmetic in Nine Sections."

It is, of course, possible that the considerable number of problems in indeterminate analysis found in the early Chinese texts are authentic and represent a kind of mathematical trait of the people. On the other hand, knowing the unreliability of the early texts, we may reasonably doubt their antiquity and hope for a more careful study of the texts than has yet been given. In particular, it is desirable to know if they are certainly earlier than the eighth century, when I-hsing (683–727), a Buddhist priest of the T'ang Dynasty (617–906), wrote on the *t'ai-yen shu*, a method of indeterminate analysis. In his case, too, since he knew Sanskrit, an interesting question arises as to how much of his *T'ai-yen* Calendar and his work in analysis was due to Indian sources.

It is said that, in the same dynasty, a Buddhist monk, I Hang, gave a problem relating to the permutations of grains of wheat on a chessboard. This leads to very large numbers and raises a question that occurs much earlier in the history of oriental mathematics—that of counting by myriads (10,000's) as used by the Greeks, Hindus and Chinese alike. It would form an interesting study to see how this device spread, perhaps through the Greek colonies (327 B. C. and later), or possibly from some common (Sumerian?) source.[13]

No further mathematical questions need concern us for nearly three centuries after the death of I-hsing. There then appeared a problem in a work by Ch'ên Huo (died 1075), president of the Astronomical Board, that deserves investigation as to its authenticity. It is to find the number of casks of wine piled in the form of a truncated pyramid having 2^2 kegs in the top layer and 12^2 in the bottom layer, the number of layers being 11. The problem is simple and its interest lies in the fact (1) that a rule for its solution seems to have been known in the "Arithmetic in Nine Sections," but not generally used thereafter; (2) that, if applied to a general case, it involves the summation of a power series; and (3) that it is similar to the problem concerning the piling of cannon balls, which becomes prominent in the sixteenth century in Europe. The questions here involved may lead to a determination of the authenticity of the text, and they suggest enough doubt to justify careful investigation.

Of all the works needing critical study those of the thirteenth and fourteenth centuries are the most prominent. This is not so much because of doubts as to their authenticity, for they are late enough to make changes in the text more readily detected, but because of the obscurity of certain statements in the works of three mathematicians, Ch'in Chiu-shao, Li Yeh and Chu Shih-chieh. These writers, living widely separated

[12] Mikami, *loc. cit.*, p. 25.

[13] On the chessboard problem see G. Vacca, "Note Cinesi," *Rivista degli studi orientali*, Vol. VI, p. 135. The problem is not the familiar medieval one of the number represented by the sum of a geometric series.

from one another, all devoted themselves to the solution of problems requiring more ingenuity than most of those of their predecessors in the fields of algebra and intuitive geometry.

Ch'in Chiu-shao[14] wrote, in 1247, the "Su-shu Chiu-chang" ("Nine Sections of Mathematics"). In this he made use of the *t'ai-yen ch'in-i shu*, or method of indeterminate analysis which is found in the work of Sun-Tsŭ already mentioned and of various other later writers. The work consists of 81 problems and in it he gives some interesting cases in the theory of numbers, areas, series, and (what is most important) the solution of numerical higher equations by a method which, in its basic principles, seems to be that which Horner first used in England in 1819, but about which (in the Chinese form) there is considerable doubt. Indeed, in general, some very critical questions have been raised respecting Ch'in Chiu-shao's work as a whole. For example, he gives a certain problem in measurement; from this he obtains a numerical equation of the tenth degree which is very much more difficult than the cubic equation which he might have used had he been even a mediocre geometer. He then states that the root is 9, which does not satisfy the equation at all. What, then, was the trouble? Did some copyist blunder, or is it that Ch'in did not himself know what he was doing?[15]

He also states a numerical equation of the fourth degree and gives a few numbers used in the solution. Upon these is based the claim that he anticipated Horner's Method, but this is little more than a conjecture.[16]

It is, of course, apparent that neither Ch'in nor Horner could be indebted to the other, and the solution is so abridged as to make it very doubtful whether there is really any relation whatever between the two methods.

The second of the Chinese algebraists above mentioned was Li Yeh (1178–1265) who wrote (1248) the "T'sê-yüan Hai-ching" ("Sea Mirror of the Circle Measurements") and (1259) the "I-ku Yen-tuan." In these works Li gives a series of problems and shows how they lead to algebraic equations, but without paying much attention to solutions; whereas his contemporary, Ch'in Chiu-shao, was concerned with the solutions, without showing much interest in the transfer from problem to equations. The work of each of these scholars was therefore the complement of that of the other.[17] There is, therefore, less need for a critical study of Li Yeh's work, unless it may be to find if his problems, which give every appearance of being original with him, are really so.

The third of the thirteenth-century algebraists was Yang Hui. In his works of 1261 and 1275 he shows much skill in summing progressions, in solving linear equations, and in attacking from the geometric standpoint the solution of a biquadratic equation. Algebra had by this time advanced far enough in China to permit of most of this work, but the question of the biquadratic needs careful consideration, especially with respect to Arab influence. It is quite probable that such influence may have resulted from the interchange of knowledge in several ways as, for example, between the astrologers in the court of Genghis Khan and those in the regions which he conquered.

[14] Ts'in K'ieou-Chao, as transliterated by Père VanHee.

[15] The question was raised, as also the next one, by Professor Gino Loria in the *Bollettino della Mathesis*, April, 1920, and was further considered by Professor R. B. McClenon in THE SCIENTIFIC MONTHLY, June, 1921, p. 517.

[16] For a conjectural restoration of the solution and the statement that "we cannot but be reminded of the celebrated method of Horner," see Mikami, *loc. cit.*, pp. 74–78; and a "remark" in *Archiv der Mathematik und Physik*, XV (3), p. 68.

[17] As to the earlier Chinese writer from whom Li Yeh obtained some of his problems, see Père VanHee, S. J., in *T'oung-pao*, Vol. XIV, p. 539.

As the thirteenth century was changing to the fourteenth the work of these three scholars was advanced in a notable degree by Chu Shih-chieh.[18] He wrote two treatises (1299, 1303) which represent the greatest advance in Chinese mathematics before the western influence made any distinct impression upon this part of the world. This was not so much because of their originality as because of their later influence in the Far East. They may be said to represent an improvement in method rather than in ability to solve equations, but this improvement was precisely what was needed to complete the work of the thirteenth century. It should also be observed that Chu constructed an arithmetical triangle by which the coefficients of the binomial series can be found, speaking of it as already known. This method is found in Baghdad at the end of the eleventh century, and may have come thence to China.

Such a possibility raises a further question as to the general exchange of mathematical knowledge between China and the South and West. This has often been considered in a general way, but specifically, as regards the details of the science, much remains to be done. The opportunities with respect to India and China were many. Those relating to China and both Persia and the Iraq region were less numerous. We are all aware of many intellectual contacts of China with her neighbors, of the influx of Buddhism, of several notable visits of Chinese scholars to India, of the translation of Sanskrit works into Chinese, of the several conquests extending to Turkestan and northwest India, and of the coming of the Nestorians, but what the specific effects were upon mathematics has yet to be discovered, and the search is by no means hopeless.

As to the introduction of Western mathematics from and after the time when the Jesuits arrived, this is too well known to need comment. We have only to consult H. Cordier's work, "L'Imprimerie Sino-Européenne en Chine" (Paris, 1901), or the summary by Père VanHee, S. J., in the *T'oung-pao* (2 Serie, Vol. XV, p. 111) to understand how great was the influence of Europe in the fields of algebra, trigonometry, and mensuration.[19] Here the question of originality hardly enters, since the indebtedness to western writers is apparent throughout.

Summarizing the matters to be considered and omitting names and dates, we need the help of expert sinologues upon the following points:

1. The authenticity of ancient texts, determined by a new and scientific study of the most (apparently) reliable manuscripts and block books extant.

2. The approximate dates of these texts and of any interpolations and commentaries, determined in the same way.

3. The evidences of foreign influence in such matters as the calendar, problems, and methods of treatment of equations, including those of the indeterminate class and the approach to determinants.

In all this work the historian of Western mathematics can assist in stating probabilities as to dates, these being based upon his knowledge of European, Indian, or Arabian achievements; but the other questions involved are for the experts in the study of ancient Chinese texts.[20]

[18] The Tschu Schi Kih of Cantor's *Geschichte der Mathematik*, 4 vols., Leipzig, 1880–1908, with various revisions. Père VanHee spells the name Tchou Che-Kie.

[19] See also his articles in the *Amer. Math. Monthly*, Vol. 33, pp. 326 and 502.

[20] One very helpful movement in this direction is seen in the recent (1930) establishing of *Études Chinoises* by Père VanHee. It announces the fact that two books on the history of Chinese mathematics are in course of preparation.

SOYA FLOUR AS A NATIONAL FOOD

By Dr. A. A. HORVATH[1]

If one will contrast the present conventional breakfast, which is almost a meatless breakfast, with the breakfast of two decades ago, one will realize that meat has been replaced by cereals, sugar, milk and fruit.—*Taylor.*[2]

ACCORDING to C. Alsberg,[3] "A national dietary which consisted entirely of primary foodstuffs, that is to say, a wholly vegetable diet, would be one that could be produced with the minimum of labor and the minimum of land."

Professor Taylor[4] has calculated that "The United States could support some 500 million people on a largely vegetarian diet, in which cereals and legumes would form the chief sources of protein, with only such animal products as could be secured from inedible residues and forage on land not adapted to the raising of primary crops."

The experience of the Chinese people is a good example that even an entirely vegetarian diet is adequate in every respect if supplemented by the use of soybean products.

The soybean is a plant of very early cultivation in China. It is mentioned in the "Ben Tsao Gang Mu," the ancient Materia Medica, written by the Emperor Shen Nung in the year 2838 B. C.

When one realizes that these beans are, and have been for upwards of one hundred generations, the principal source of protein in the Chinese diet, and when one further considers the sustained hard manual work that the Chinese are capable of, as well as their mental virility, and the high state of their culture in a period when Europe and America were barbarians, it will be understood that the question of this diet is worth studying to introduce it in the dietary of this country.

It took 300 years after the introduction of the potato into Europe for its use to become general, but in these days of wide publicity and the public's more intelligent appreciation of food values, it should take but a very short time for the use of soya meal to become universal since it has five times the calorific value, twenty times the protein value, and two hundred times the fat value of potatoes. It should become a national food in every sense.[5]

In the United States, over 3 million acres are under the cultivation of this bean, and there are indications that it is gaining popularity as a food article,

[1] Till recently, of the Rockefeller Institute for Medical Research, Princeton, N. J. (Former head of the Soybean Research Laboratory at Peking Union Medical College, Peking, China.) "The Soybean as Human Food," a monograph published by the Bureau of Industrial and Commercial Information, Ministry of Industry, Commerce and Labor, National Government of the Republic of China, 2d ed., 1930, Shanghai; *J. Biol. Chem.*, lxviii, 343, 1926; *Jap. Med. World*, vii, 105, 1927, and viii, 1, 1928; *Amer. J. of Physiol.*, xciv, 65, 1930.

[2] Of the Food Research Institute, Stanford University. From an article entitled "Consumption, Merchandising and Advertising of Foods." *Harvard Business Review*, II, 283, 1924.

[3] Director of the Food Research Institute, Stanford University. From an article entitled "The Effect of Scientific Food Consumption in Increasing Wealth." Ann. American Academy of Political and Social Sciences, cxv, 1924.

[4] From an article entitled "The Future Food Supply of the United States." *Bull.* New York Academy of Medicine, November, 1927.

[5] According to Pearl, in this country the average diet of a few years ago, as ingested, contained 114 gms of protein, 127 gms of fat and 433 gms of carbohydrates, corresponding together to about 3,424 calories per adult man per day. The soybeans seem to become a valuable source of cheap protein and fat, as predicted fifty years ago by Professor Haberlandt.

due to its high nutritive value and the strong support given it by various scientific and business organizations and the U. S. Department of Agriculture with the Bureau of Home Economics. The American Soybean Growers Association is also doing its best to promote interest for this outstanding seed.

The composition of common American varieties of soybeans is the following:[6]

Variety	Moisture, per cent.	Protein, per cent.	Fat, per cent.	N-free extract, per cent.	Fiber, per cent.	Ash, per cent.
Mammoth	7.49	32.99	21.03	29.36	4.12	5.01
Ito San	7.42	34.66	19.19	27.61	5.15	5.97
Haberlandt	8.67	36.59	20.55	24.41	4.00	5.78
Guelph	7.43	33.96	22.72	25.47	4.57	5.85
Midwest	8.00	35.54	19.78	26.30	4.53	5.85
Kingston	7.45	36.24	18.96	26.28	4.79	6.28

The soybean is remarkable for its richness in protein, fat and mineral matter, as can be seen by comparison with other foods:

	Protein	Fat
Lima bean	18.1	1.5
Eggs	14.8	10.5
Lean meat	19.2	10.7
Whole wheat	12.2	1.7
Milk	3.20	3.50

The soybean contains double the amount of the protein and calories present in beefsteak.

The nitrogen-free extract of the soybean is composed chiefly of dextrin (3.14 per cent.), galactan (4.86 per cent.), pentosan (4.94 per cent.) and sucrose (3.31 per cent.). Starch is present only in traces,[7] while in cereals starch is the chief ingredient.

[6] Data of the Tenn. Agr. Exp. Sta.

[7] It makes the soybeans a valuable food for diabetics. See von Noorden; and Friedenwald and Ruhräh, *Am. Jour. Med. Sci*, cxl, 793, 1910.

The soybean protein (glycinin) is a complete protein containing all the essential amino-acids necessary for the building up of the proteins of the human organism. Glycinin is very similar in properties to the casein of milk, being coagulated by acid. According to Osborne and Mendel,[8] the proteins of the soybean, unlike those of the other leguminous seed, are adequate for promoting normal growth. A soybean diet increases the protein content of the blood (Horvath).

Rose and MacLeod[9] demonstrated that the human organism is able to store three times as much nitrogen from a soybean food as from meat.

According to Dr. Tso,[10] for use in feeding babies, the soybean proteins are comparable to cow's milk protein. Recently forty babies were successfully fed at the Department of Pediatrics, Harvard Medical School, for a period of two months and more, a diet with soybean flour as the sole source of protein (Hill and Stuart).

According to Dr. Kupelwieser,[11]

> Soya flour proved to be a protein source of hitherto unparalleled cheapness. That we need have no hesitation in making use of it, and that with it the white race can also cover a very considerable part of its protein requirements, has been fully demonstrated by nutrition experiments extending over a long period carried out on children, the half of whose daily protein requirements was given to them in the form of soya flour.

Refined soybean oil has been studied with other oils in a series of experiments carried on by the office of Home Economics of the U. S. Department of Agriculture, and found to compare favorably with the more common culinary table oils with respect to the thoroughness with which it can be assimilated.

[8] Of Yale University. See *Jour. Biol. Chem.*, xxxii, 369, 1917.

[9] Of Professor Sherman's Nutrition Laboratory, Columbia University. *Jour. Biol. Chem.*, lxvi, 847, 1925.

[10] *Chinese Jour. of Physiol.*, iii, 353, 1929.

[11] Of the University of Vienna.

Lecithin (a phospho-lipoid) is present in the soybean to an extent of 1.64 per cent. Lecithin is an important constituent of all organs of the human body and especially of the nervous tissue, the heart and the liver. The percentage of lecithin in those organs raises while on a soybean diet (Horvath).

Cephalin (a phospho-lipoid) was found in the soybean by Levene and Rolf.[12] Cephalin forms an essential part of the substance of the brain.

The ash of the soybean is alkaline, while the ash of other cereals is acid (Nuzum, Osborne and Sansum).[13] The ash is rich in phosphates (31.52 per cent. of P_2O_5). A soybean diet raises the phosphorus content of the blood (Horvath).

The calcium content of the soybeans is 0.26 per cent., while that of cow's milk is around 0.16 per cent. They contain an excess of fat in regard to the ratio calcium: fat required for optimal absorption and metabolism of calcium salts.[14] If supplemented by wheat flour, reducing the percentage of fat in the mixture, the soybean diet keeps the blood calcium at a normal level (Horvath).

So far as we are aware, the soybean is the only seed which contains both the water-soluble and the fat-soluble vitamines (Osborne and Mendel; Daniels and Nichols).[15] The presence of vitamines A and D was demonstrated particularly by Hornemann,[16] and the vitamine A content recently by Scheunert.[17] Both vitamines B[18] (B_1 and B_2, otherwise termed F and G) were found. The fertility vitamine E is also present (Daniels and Hutton)[18a], as well as vitamine C. A diet of germinated soybeans increases the clotting capacity of the blood (Horvath).

It can be seen that, from the point of view of its chemical constituents, its physiological value and its richness in vitamines, that the soybean occupies an outstanding place among the foodstuffs.

Since it is quite difficult to boil soybeans to softness, they were used by the Westerners mostly in the form of flour, 20 per cent. of it being mixed with wheat or rye flour (or both) in the manufacture of bread, and good results were recorded.

In this country, Johns and Finks,[19] using a soybean bread,[20] found "that the mixture of soybean and wheat proteins is much better utilized than the wheat proteins alone. Comparisons show that for the same amount of food consumed, *the soybean bread diets are about two or three times as efficient as the wheat bread diets.*"

In Italy, extensive studies along this line were conducted on men by Professor Ducceschi[21] of the Committee for the Study of the Soya.[22]

Six normal individuals were kept by Ducceschi for a period of from 4 to 6 days on a sole diet of a 10 per cent. soybean bread.[23] The average daily ration was 739 gms of bread per capita with a

[12] *Jour. Biol. Chem.*, lxii, 759, 1924–25.

[13] *Arch. Int. Med.*, xxxv, 492, 1925.

[14] As is the case also in excess fat milk.

[15] *Jour. Biol. Chem.*, xxxii, 91, 369, 1917.

[16] *Z. Unters. Nahr. u. - Genussmittel*, xlix, 114, 1925.

[17] *Fortschritte der Landwirtschaft*, 3 Jahrg., H. 24, 1928.

[18] The anti-beri-beri and anti-pellagric vitamines.

[18a] *Jour. Biol. Chem.*, lxiii, 143, 1925.

[19] Of the Bureau of Chemistry, U. S. Department of Agriculture. *Amer. Jour. Phys.*, lv, 455, 1921.

[20] A 15 per cent. soybean bread of "war flour" contained 13.3 per cent. protein. They used up to 25 per cent. of soybean flour for bread.

[21] Director of the Physiological Institute of the University of Padova, Italy. Atti della Societa Medico-Chirurgica di Padova, Italy, 1927.

[22] Founded by order of Premier Mussolini.

[23] Military whole wheat flour and 10 per cent. extracted soybean flour (54.89 per cent. of protein in dry substance). To supplement the shortage of fat, 25 to 30 gms of butter were used with the bread.

protein content of 97.3 gms and 2,940 calories.

The utilization of this 10 per cent. soybean bread was:

Total absorption of the dry substance	93.72 per cent.
Total absorption of the calories	93.84 " "
Nitrogenous substance	83.90 " "
Fat	94.13 " "
Carbohydrates	96.59 " "
Mineral substance	68.60 " "

The conclusion was:

The research performed on human individuals on the intestinal utilization of the nitrogonous substance and its relationship to the metabolism of nitrogen during a sole diet of bread containing 10 per cent. of soybean flour demonstrated that this bread was in appearance, digestibility and utilization equal to a bread from only wheat of best quality, having the advantage of containing a higher per cent. of nitrogenous substance.

A sole diet of a 20 per cent. soybean bread[24] was tested on two normal individuals for a period of five days consisting of 831.5 gms of bread, containing 127.6 gms of protein and 3,272.8 calories per capita per day.

The utilization of the 20 per cent. soybean bread was:

Total absorption of the dry substance	92.41 per cent.
Total absorption of the calories	92.48 " "
Nitrogenous substance	80.30 " "
Fat	95.70 " "
Carbohydrates	97.01 " "
Mineral substance	62.53 " "

Although the assimilation is in this case slightly below the preceding, the figures lie, according to Ducceschi, within the satisfactory limits for white bread.

The general conclusion of Professor Ducceschi can be quoted as follows: "The soybean flour, if added to bread or other nutritive food preparations, is going to become a valuable supply of cheap protein for the alimentation of the people."

Before the war, around two tons of extracted soybean flour[25] were used daily by the bakeries in Hamburg, Germany, for bread and, since 1920, a 10 per cent. soybean bread is supplied in Hamburg to hospitals, asylums, and other public establishments. To quote the authoritative words of Professor Neumann,[26] "The heads of the hospitals were unanimous in their praise of this bread, since there was nothing to wish for in regard to taste and utilization."[27]

The manufacture of a similar 10 per cent. soybean bread was begun in 1920 also in the coal-mining and industrial districts of Bochum, Dortmund and Düsseldorf in the Ruhr (Germany). Here the soybean bread is of particular importance for greater efficiency of muscular work, due to the high physiological value of its protein, the richness in phosphates, and the alkalinity of its ash. It was shown recently that the administration in the morning of phosphates on days of hard exertion markedly relieves fatigue.[28] And it is a well-established fact, too, that muscular work lowers the alkaline reserve of the blood by floating the blood with lactic acid, etc. Ordinary bread (wheat, rye, and others) is acid forming in itself and the addition of the physiologically alkaline soybean flour to it is thus contributing to higher efficiency of the work.

Complete metabolic experiments regarding the utilization by men of soy-

[24] Supplemented by 25 to 30 gms of butter, as in the previous experiment, since the soybean flour was deprived of oil by extraction.

[25] Of the Hansa Mill, Hamburg.

[26] Director of the governmental Hygiene Institute in Hamburg, the largest institute of its kind in Germany. *Archiv für Hygiene*, ic, 1, 1928.

[27] The addition of 10 per cent. extracted soybean flour to a wheat-rye flour (60 per cent. rye and 40 per cent. wheat) of 70 per cent. milling yield raises its protein content from 6 to 8 per cent. 15 per cent. soybean flour brings the protein content to 10 per cent.

[28] Muscular work is accompanied by a loss of phosphates derived from the muscular tissue.

bean bread as a sole diet (500 to 750 gms of bread) were conducted recently (1928) by Professor Neumann, director of the Hygienic Institute in Hamburg, on ten normal individuals for periods of from 4 to 5 days. Various flours were tested. A 20 per cent. bread baked from extracted soybean flour (of the Hansa Mill) showed 79.61 per cent. utilization for protein, 95.91 per cent. utilization for carbohydrates and 91.75 per cent. utilization for calories.

Numerous soybean flours have been on the markets of Europe and the United States for the last fifteen years, but none of them, with one exception,[29] can claim to have met with real success for the following reasons:

1. *Whole ground bean flour* has a peculiar beany taste, and can not be kept or transported on account of its rapid deterioration. It acquires in a very short time a bitter taste and a repugnant flavor. Its oil turns rancid and its fat soluble vitamines (A and D) are destroyed. Such a deteriorated flour, if ingested in any form, is toxic, causes disturbances of the digestive tract and destroys the fat soluble vitamines ingested with other foods (Fredericia). It was found by experiments on albino rats that the longevity on whole soybeans is greater than on ground whole soybeans.

2. *Soybean flour prepared from press cake* is subject to the same criticism, since the press cake still contains 5 to 8 per cent. of oil. Such a flour deteriorates even more rapidly, due to the excess of moisture and the more thorough breaking up of the bean cells.

3. *Extracted soybean flour* is not subject to rancidity more than ordinary wheat flour, since most of the oil is removed. But such a flour has the peculiar beany taste and is deprived of the highly valuable constituents—the lecithin and the vitamines A and D.[30] Besides, the solvent used in denaturing the soybean protein and the removing of the solvent by steam is often incomplete, thus rendering the extracted flour toxic.

The market flours obtained either from whole soybeans, press cake, or extraction meal, all possess, in addition, the disadvantage of being milled from unshelled beans. And it was recently shown by Neumann[31] that the presence of shells in soybean flour reduces the longevity to 70 per cent. in comparison with a diet of shelled beans.

Professor Neumann's authoritative conclusion is that "*Soybean flour, either for use in the kitchen or for baking of bread, must be manufactured exclusively from shelled beans.*"

The problem of eliminating the beany taste and peculiar odor of the soybean without injuring its valuable qualities has been occupying the attention of a number of scientists and industrialists. The majority performed nothing but the simple operation of roasting soybean flour from press cake, and felt justified to put it on the market labeled as "health flour." The writer noticed, in 1923, that the water in which the beans were soaked contained a large part of the odoriferous substance, and that a part of the beany taste was eliminated during germination. These observations indicated that the specific substances are located somewhere in the superficial layers of the bean cotyledons, and that germination can be used for improving the taste of the bean and consequently bean flour. But it was found rather difficult to obtain a uniform product of a standard quality, as the manufacturing expenses were high, and the flour dark in color.

Recently the problem of the utilization of the valuable constituents of soya for human food has entered on a new phase, for Berezeller,[32] working in Vienna, has devised a

[29] Berczeller's soybean flour.

[30] They are all extracted with the oil.

[31] On mice.

[32] Professor of the University of Vienna, Austria. *Biochem. Z.*, cxxix, 313, 1922.

special process of milling, combined with fractional distillation, whereby the obnoxious constituents can be removed and a meal of high nutritional value obtained. This special soya meal forms a slightly yellowish flour of agreeable and appetizing appearance and a faint almond-like taste. It differs from the product obtained by the simple milling of the bean in its complete freedom from bitter flavor and its capacity of being stored practically indefinitely without turning rancid (Professor Parsons).[33]

A sample of Professor Berczeller's patented soybean flour "Soyolk" was analyzed by the writer and gave:

Water	7.37 per cent.
Fat	19.64 " "
Lecithin	1.38 " "
Protein	42.12 " "
Nitrogen-free extractives	23.40 " "
Crude fiber[34]	1.33 " "
Ash	4.76 " "
Total	100.00 per cent.

According to Dr. Kupelwieser,[35] 1 kg of "Soyolk" flour is equivalent in caloric value to 3.63 kgs lean boneless beef, or to 57 eggs, or to 6.5 liters of cow's milk, while, in respect to protein contents, 1 kg soyolk flour is equivalent to 2.05 kgs lean boneless beef, or 67 eggs, or 13.7 liters of cow's milk.

Berczeller succeeded in freeing the soybeans of their specific taste, and in retaining their fat in a condition in which it is not liable to turn rancid, as stated by Professor Durig[36] and others. This phenomenon can perhaps be explained by the elimination during the process of distillation of some volatile fatty acid acting in untreated beans as a catalyzer for the oxidation of oil.

Eggs and fish roes are perhaps the principal source of lecithin[37] (organic phosphorus) but "Soyolk" flour contains more of this valuable constituent than any other vegetable food, and, when one considers its price, it will be found that it is a cheaper means of obtaining this nerve and brain food than eggs. One pound of "Soyolk" flour contains lecithin equivalent to six eggs.

Berczeller's flour does not produce obesity in spite of its high fat content—a fact due to the peculiar quality of its lecithin[38] and oil, which enables the organism to utilize them in the organs and tissues instead of storing them in fat depots. This was confirmed by the writer who found a higher lecithin content in the heart and liver of animals fed Soyolk flour.[39]

Soyolk flour contains also the valuable fat-soluble vitamines A and D, which are deficient in the food of the white race. Recent studies by Seifried have shown that if the diet is deficient in vitamine A, a degeneration in the glands of the body is taking place. The mucosa of the nasal cavity and respiratory tract is finally desquamated, giving way to a secondary bacterial invasion, resulting in severe rhinitis, sinusitis, tracheitis, bronchitis, etc. Conjunctivitis is also very common. Similar changes are observed also in other vital organs. Professor Van Leersum[40] found in vitamine A deficiency calcification of the epithelium of the kidney.

Haugue found recently an indication of the existence of a close physiological relationship between the yellow color and the formation of vitamine A. The

[33] From an article entitled "The Use of the Soy Bean in Human Nutrition" in *The Lancet*, ccxii, 267, 1927.

[34] The low fiber content is due to the removal of the shells from the beans before their being treated.

[35] Of the University of Vienna.

[36] Director of the Physiological Institute of the University of Vienna.

[37] Milk and butter are deprived of lecithin.

[38] Hesse found that lecithin of vegetable origin does not produce obesity. And Bloor showed that lecithin is in charge of the transport of fat in the body.

[39] Professor Kafemann is recommending since 1913 the use of soybean flour for treatment of alcoholism. This investigator showed that the heart muscle of alcohol-intoxicated animals contained only one half of the amount of lecithin present in the hearts of normal animals. *Allgem. Med. Centr. Zeit.*, No. 41, 1913.

[40] Of the Netherlands Institute of Nutrition, Amsterdam, Holland.

yellow color of Berczeller's Soyolk flour from this point of view is a highly valuable quality.[41]

The presence of vitamine A in Soyolk flour renders it particularly valuable for engineers, miners and factory workers exposed to sudden changes in temperature, dust, excess moisture, etc., as it increases their resistance to the diseases of the respiratory tract and particularly to sinus troubles. On account of its vitamine D content, Berczeller's Soyolk flour is of special value for "indoor" persons who are deprived of the beneficial effect of the ultra-violet radiation of the sun (working in underground galleries, under roofs, in buildings with windows of ordinary glass, etc.).

The physiological alkalinity of the ash of Soyolk flour and its richness in phosphates renders it highly valuable for miners and hard muscular work in general, relieving fatigue and thus increasing their efficieney.

Professor Van Leersum (Amsterdam) proved, in 1929, by direct experiment that Berczeller's Soyolk flour is rich in the vitamine B_2, indicated in this country as vitamine G.[42] This vitamine is of particular interest to this country since it is capable of preventing a disease called pellagra, which has been, since 1906, a horror to the South. In the springtime, it strikes people whose winter diet has been confined too closely to corn and pork.[43] It is of importance to notice that in China where soybeans form a part of the daily ration of the people, only single cases of pellagra are reported among a 400 million population.

Experiments on pigeons fed a diet of polished rice and Berczeller's soybean flour showed the presence of vitamine B_1 (F).

Comparative studies by Professor Neumann show that the utilization of Berczeller's soybean flour by man (in the form of a 20 per cent. bread) is superior to that made from extracted bean flour, as can be seen from the table:

	Utilization of nitrogen	Utilization of carbohydrates	Utilization of fiber	Utilization of ash	Utilization of calories
Wheat-rye bread[44] containing 20 per cent. of extracted soybean flour	79.61	95.91	51.93	67.94	91.75
Wheat-rye bread[44] containing 20 per cent. of Berczeller's soybean flour	80.40	98.58	55.22	76.07	94.96

Berczeller's flour showed, according to Professor Neumann, a utilization of carbohydrates superior even to the utilization of starch in bread.

Berczeller's flour was studied by the Hungarian Food Ministry with the following conclusions drawn:

> The flour is of a pale yellow color, has a slightly sweet, agreeable, almond-like flavor and, in spite of its high percentage of oil, is but slightly fatty. . . . The soya flour prepared by the Berczeller process can supply a great part of man's demands for protein, and this, too, continually and for a long time.
>
> It can be extensively used in the preparation of bread, puddings, meats (sausages, hashes).
>
> It is of paramount interest in the question of hygienics and national economics that the

[41] Soyolk flour has found a large market in Holland among the manufacturers of margarine. The oil, lecithin and vitamines A and D are extracted from it by means of a solvent, and this extract added to margarine, rendering it rich in vitamines and lecithin. The oil extracted from Berczeller's Soyolk flour is in quality and taste superior to refined bean oil, which is, besides, deprived of vitamines and lecithin.

[42] The growth-promoting vitamine.

[43] Special attention was given to vitamine G on the program of the meeting of the American Chemical Society at Atlanta on April 7.

[44] Rye flour 60, wheat flour 40, milling yield of 70 per cent.

extension of the soya consumption be materialized in the near future, and this can be accomplished chiefly by subsidizing the extension of soya consumption by the state.

Berczeller made a noble gesture in making a gift of his patented procedure in Hungary to the Children's Welfare Society of that country. At present, factories manufacturing Berczeller's flour are also established in Austria, Germany and England, and the introduction of Soyolk flour has met everywhere with great success.[45]

Among the various methods of using Dr. Berczeller's "Soyolk" flour, in providing human nutrition, its use in bread making is undoubtedly of the highest importance from the point of view of the hygiene of nutrition and also of social economics.

Soyolk flour has about four times as much protein as the cereals, and twice as much as the pulses. The contents of fat is fifteen to twenty times higher in soyolk flour than in wheat or rye flour. It is impossible to make bread from soya flour only,[46] but it serves to enhance the nutritive value of bread and to improve the quality of bread from a technical point of view.

Very small quantities of Soyolk flour, blended with the ordinary white flour, result in a flour mixture which possesses all the physiological characteristics of dark wholemeal flour, and bread made from it surpasses the nutritive value of bread made from whole wheat. Its flavor, taste and bloom are the same, if not superior to white bread. For 10 per cent. bran,[47] one can substitute 5 per cent. of Soyolk flour in white flour and obtain a bread with 20 to 25 per cent. more protein and 2½ per cent. more fat. Through using soya flour in breadmaking, we not only increase the protein value of this vital part of our food, but, at the same time, we substitute the more expensive daily needs of animal protein.

F. A. Richter, baking expert of the Nutrition Laboratory of Vienna, made extensive experiments in the laboratory and partly in the factories in order to examine the various processes of breadmaking by using certain percentages of Berczeller's Soyolk Flour. His statement follows:

We took special care not to deviate from the customary flavor, taste and outside appearance of the various kinds of bread used in different countries (England, Scotland, Wales, Ireland, France, U. S. A., etc.). In none of these tried methods of making bread by adding soya flour in the above proportions could any essential change in flavor, or texture, be discovered in the bread. On the contrary, it improved the flavor of a Viennese roll and gave it a tempting appearance. We can say the same of the dark loaf of Germany, of the American cream cracker biscuit and the English wholemeal loaf.

In the same way we have examined white and black breads fermented with yeast and leaven, and in making rye, wheatmeal, malted bread, etc., in the different ways. Exact comparisons with and without the new soya bean flour were recorded, and every impartial visitor could observe an improvement in the quality.

With such small additions of soya flour, it is not at all necessary to alter in any way the method of fermentation or of baking. As for the technology of baking, we find the following advantages by the use of the new soya flour:

1. Very small additions of soya flour enhance considerably the keeping qualities of the bread, owing to the higher quantity of protein and fat. These last qualities can also be observed in milk bread, and this is the reason why addition of fat is recommended. These observations have been testified to by a large number of bakers and by official experiments in the chemical institutes of Budapest.

2. The Berczeller soya flour has a much stronger water-absorbing capacity than ordinary flour. In proportion to the addition of new soya flour, the yield in dough and baked

[45] In Italy, Mussolini declared to Dr. Berczeller his intention of introducing legislation to compel the use of soya flour in the manufacture of polenta, the staple maize food and bread (cit. by Hay). In the United States the building of a Soyolk factory is under way.

[46] Due to the absence of gluten.

[47] Wheat bran contains: protein 16.85 per cent.; fat 5.22 per cent. Soyolk flour contains: protein 42.52 per cent.; fat 20.24 per cent.

bread is a larger one. In caloric value the soya bread is still higher than ordinary bread.

3. We also note a saving in yeast, as the new soya flour aids fermentation, because the soya flour supplies the right quantities of the most suitable nourishment for the yeast.[48]

4. The new soya flour gives to the loaf a beautiful bloom and a pleasant tasting crumb and crust. This is due to the large amount of protein and fat in the soya flour.

5. The use of small proportions of the soya flour with the dark rye flour for the making of dark breads, which are customary in various Continental countries and in Russia, results in a bread of remarkably lighter color in the crumb and crust. The demand for whiter and, at the same time, more sustaining bread can be met in a quite inexpensive way.

Very pleasantly flavored and easily digested breads can be produced to supply the daily and necessary wants of proteins and fat for the proper nutrition of man. These breads have remarkable keeping qualities and are especially suitable for the manufacture of such kinds of bread, or similar articles, which are an integral part of the provisions for expeditions, tours, etc. In milk bread and in practically all kinds of fancy bread and rolls, where the new soya flour can substitute a substantial part of the milk, an addition of 6½ to 18 per cent. of the new soya flour is to be recommended. The nutritive value of such milk bread is superior to bread made with cow's milk. The physiological qualities and the taste are entirely substituted. Extraordinary savings are effected in the production of all kinds of small goods, such as fancy milk tea cakes, rolls, buns, scones, or anything of this nature. We not only save milk, but also yeast, malt and fat. A new economical factor enters into the business of the baker and pastrycook, both for his own benefit and the benefit of the consuming public.

Richter further extended the study of the uses of Soyolk flour for the manufacture of biscuits, pastries and confectionery goods, chocolate marzipan, custards, vermicelloes, macaronies, etc., and worked out a number of very good recipes. In Richter's opinion, Soyolk flour "acts as a perfect substitute for eggs, fat and milk, besides enhancing the nutritive value of these products." In this country, excellent doughnuts were recently manufactured with Soyolk flour without any milk or eggs.

Soya biscuits are cheaper and "outstanding because of their large content of proteins and fat. The ideal food for the feeding of children, nursing mothers, convalescence."[49] "The great advantage in the use of these articles made with the new soya flour is that it curbs the tendency in so many people to put on fat."

We must also remember that, for the young growing organism, the mixture of the soybean and wheat proteins were found two or three times more efficient than the proteins from wheat alone (Johns and Finks).

Also, a number of valuable infant foods and cow's milk substitutes can be manufactured from Soyolk flour.[50]

The Berczeller soya flour is suitable for mixing up to 50 per cent. in all kinds of sausages. It must be specially emphasized that the soya flour not only replaces the weight of the meat itself, but also absorbs a considerable amount of water (at least as much as its own weight). In the manufacture of sausages the soya flour is first mixed with an equal quantity of water, and then mixed with the mincemeat and made into sausages in the usual way. Sausages prepared in this way are extremely palatable. From a physiological point of view the introduction of soya flour into sausages can be regarded in no

[48] The addition of soya flour to pressed yeast cake is being successfully tried in this country by some companies. Soya flour is also inserted in the patented yeast powders for the baking industry, shortening the ripening of the bread.

[49] Professor Moll, of the State Institute for Mothers and Children in Vienna (Austria), has obtained very satisfactory results with Soyolk flour for weak and tubercular children.

[50] Ruhräh has shown the high efficiency of soybean preparations in the treatment of summer diarrhea in children. *Amer. Jour. Med. Sci.*, cl, 502, 1915. More information in regard to the use of soybean preparation in disease can be found in the text-book on nutrition of Von Noorden and Salomon. "Handbuch der Ernährungslehre," Berlin, 1920.

other way than as an improvement, since the soya flour contains only traces of purine bodies, thus preventing the development of gout.

In Vienna, Mrs. Hess, the head of the Federal Institute for Home Economics, undertook the study of the application of the Soyolk flour to cooking. Soon a large number of recipes were produced, the principal of which were soy-soups, meat dishes, cakes, fish salads, pancakes, etc.

In this country, the Bureau of Home Economics of the U. S. Department of Agriculture elaborated a long list of excellent recipes including common soya flour a few years before the Soyolk flour became known. These recipes are only gaining if Soyolk flour is used.[51]

For conclusion, the authoritative opinion of Professor Durig is quoted as follows:

> If soya flour can be successfully supplied in such a way that it really does not deteriorate and is as valuable for nutrition and appetizing as the samples forwarded as tests, and if, further, one succeeds in marketing the flour at a proportionately moderate price, a feat has been accomplished of incalculable significance for social economy, since it makes it possible to supply a source of protein in a degree which has never been attained by any other food. Not only in the question of feeding the people at large, but also—and that in a very special degree—with regard to feeding the public institutions, the prisons and the hospitals, prospects of great social economical importance are opened up.
>
> At the same time, one must not forget that national food questions are never to be solved from the standpoint of theoretical considerations, however correct these considerations may be, as the deciding factor is always custom and taste, and, especially, the tendency of people to seek a certain enjoyment value in their food, even when they know that they have to pay a high price for it. In any case, in spite of difficulties in carrying through an innovation such as the introduction of soya flour into the nation's food, it is highly desirable that the question of producing some soya flour which will satisfy all the requirements of durability, full biological value, edibility and technical exploitability be energetically taken in hand and that, once and for all, a beginning be made with the extensive use of soya flour, which was also recommended by C. V. Noorden. The social political significance of this question is beyond all doubt.

[51] For further references on this subject, see articles by Fridericia in the *Journal of Biological Chemistry*, lxii, 471, 1924; by Hill and Stuart, in the *Journal* of the American Medical Association, xciii, 985, 1929; and "The Soybean" (1923) by Piper and Morse.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

EPIDEMIC POLIOMYELITIS OR INFANTILE PARALYSIS

By Dr. WILLIAM H. PARK

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In the United States poliomyelitis occurs usually in young children and this is the reason it is commonly called infantile paralysis. In the Northern States cases usually begin to appear during June and increase during July and August. The disease diminishes in October and practically disappears in November. In the Southern States it may appear somewhat earlier and last longer. Last year outbreaks occurred in California and in the Middle West, while during the present summer we are having rather more cases in the Eastern States. The age of the children attacked varies. This year in New York City about 70 per cent. of the cases have occurred in children under five. There have been as yet no cases in children over 15.

The Nature of the Virus—We have not as yet been able to cultivate it on culture media in the same way as we do diphtheria bacilli or scarlet fever streptococci. We know, however, that the poliomyelitis microbes are much smaller than these for they pass through the pores of porcelain filters. They are invisible to us even with the greatest magnification possible.

For a long time it was thought that no animal was susceptible to the disease, but in 1909 the actual transmission of the virus of infantile paralysis in monkeys was announced by Landsteiner and Popper. Very shortly after their work was reported, Flexner and Lewis confirmed their work and transmitted the disease from monkey to monkey. The virus was found to be fairly resistant and to live for a considerable length of time outside of the human body. At present then we know that the virus is filterable and that in a developed case it is located in the gray matter of the spinal cord and to a lesser degree in the gray matter of the brain. When the spinal cord of a fatal case is placed in pure glycerin the virus lives in it for long periods of time. As it takes a considerable amount of virus to infect a monkey, bacteriologists have had great difficulty in studying the location of the virus before it invades the central nervous system and there multiplies greatly. Flexner found the virus existing in the throat secretions of a convalescent case. Swedish investigators believe that they proved the virus to be present in the pharynx and intestines of a number of healthy persons who were in contact with cases as well as in the actual acute and convalescent cases. We have other evidence that makes us believe that the germs of infantile paralysis are very widely spread and that only in a small percentage of the people infected does the virus penetrate to the blood and into the spinal marrow. This information has come to us in a peculiar way. It was discovered by Flexner that the serum of monkeys which had recovered from infantile paralysis would give protection to other monkeys as is shown by the fact that they resisted the inoculation of the virus. The next step was to find that

human beings who had recovered from the disease also possessed a considerable amount of antibodies. Doctors Zingher and Neal from my laboratory used this convalescent serum extensively in New York in the epidemic of 1916. To Dr. Zingher it seemed to give striking effects in the cases when it was given before paralysis had developed. The paralysis usually not appearing in such cases. Dr. Neal was less certain as to the value of the serum.

Lately Dr. Aycock working with Dr. Rosenau and other members of the Massachusetts Infantile Paralysis Commission and the International Committee For The Study of Infantile Paralysis, whose work has been financed by Mr. Jeremiah Milbank, has used it very extensively in the metropolitan area about Boston, and believes with Dr. Zingher that it gives very striking effects. Almost everyone doubts the value of the antiserum if it is given after paralysis has developed. Not only Dr. Aycock in Boston but Dr. Weyer in my laboratory, discovered that a large proportion of the adults and older children had this antibody. This discovery indicated that the virus was widespread for as far as we know, these specific protective substances only develop after an infection. I say infection, not a definite disease. For instance, we know that in an institution in which diphtheria has developed, that besides the few cases which had developed diphtheria, there were a great many others who became immune as shown by the Schick test. If cultures are made from time to time during such an outbreak from the throats of these children, many show diphtheria bacilli. That is they were infected but the infection had not gone far enough to produce actual clinical disease. Again we know that many persons have the germs of pneumonia in their throats. Some of these are healthy, others have a tonsilitis or a rhinitis or occasionally a pneumonia. The same we believe to be true for infantile paralysis. The virus probably spreads to many persons creating in some almost no disturbance whatever, in others a little irritation of the mucous membranes. In only a small percentage of these persons does infection pass to the spinal cord and to the special nerve cells which influence muscular action. These are the only ones which develop paralysis. We believe it is for this reason that older persons become immune and the disease is so liable to be largely confined to young children. Because infantile paralysis is more or less endemic in this country, we believe the germs in other than epidemic times have less virulence, so that only a very occasional child develops the disease while the majority of persons become immune.

Can we do anything to stop the spread of the disease? Something but not very much. There are certain things that we know. The infection is spread by the infected secretions of human beings; the nasal secretions, the throat secretions, the intestinal discharges. This material when expelled from the human body remains alive for some days or weeks. In two instances the virus was transferred to a few children in raw milk. If it comes in contact with the mucous membranes of very susceptible children, some light infections and some severe ones will probably develop in a fair proportion of the cases. We try therefore to limit as far as possible, the contact of those who may be infected with those who are not infected. Therefore, we treat any case of infantile paralysis in the same way as we would a case of diphtheria. The secretions from the eyes, the nose, the mouth and the intestinal discharges are immediately disinfected. The one who nurses the child abstains as far as possible from mingling with healthy children. We have the valuable experience that children in the institutions which are carefully isolated during an outbreak of infantile paralysis rarely become infected, while those

admitting visitors freely from regions where the disease is prevalent, are apt to develop it.

The Question of Summer Camps—While we are not sure that it is necessary we think it wise to limit or stop the visiting of children by their parents and friends when in camps. These visitors may be admitted to the camps if they are prevented from actually coming in contact with the children.

General Treatment of the Sick—It is known that children suffering from infantile paralysis have a better chance for final recovery if they are kept at rest when first attacked. This causes us to prevent, as far as possible, the moving of discovered cases in a camp, by railroad or by other means for long distances. That is, a child in a camp should be removed to a neighboring hospital and not to a distant city from where the child came.

What Medical Treatment is Available—As already stated we believe before paralysis develops that an intraspinal and an intramuscular injection of the serum from a convalescent case of infantile paralysis or of horse antiserum prepared from an immunized horse tends to abort the disease. We are not absolutely sure of this but we have good grounds for it. We know that an injection of serum in a monkey would protect the monkey from the development of the disease if it is later infected.

Preventive Treatment—Occasionally a second case develops in a family. We believe therefore that it is advisable to inject the children in a family where a case has just developed. When paralysis has developed we know of nothing that influences the development of the disease.

Bacteriologists working under the International Committee for the Study of Infantile Paralysis have been trying to find some curative drug remedies and have made some progress but none sufficiently definite to be employed in routine practice. It seemed that some severe cases might get well if they could be prevented from dying of suffocation. An apparatus has been developed, called the "Drinker" apparatus, in which a child can be placed and artificial respiration kept up without disturbing the child in the least. The original purpose of this apparatus was to help those who were unable to draw air into the lungs because they were paralyzed. Some lives can be saved by the Drinker apparatus but many of the cases die in spite of it from the effect of the general poisoning. The children really enjoy it.

During the first few weeks of the disease, rest is the best remedy. Later under the guidance of the physician, electrical and careful massage treatment may be given and of course various forms of apparatus applied to relieve the muscles which have suffered degenerative changes.

Infantile paralysis almost never affects the intelligence. The injury done is confined to the nerve cells and the muscle fibres supplied by them. Usually a small or a larger group of muscles is wholly or partially affected. When the convalescence is established we try to do what we can to strengthen the muscle fibres left intact in a muscle or if this is impossible we try to accustom other muscles to take over to some extent the function of those injured. It was discovered that those who have suffered from muscular atrophy because of paralysis can be benefited by exercising while in the water. Almost everyone in the United States knows that Franklin D. Roosevelt, the Governor of New York, suffered in the prime of his manhood from an attack of poliomyelitis, and that he has succeeded largely in overcoming its ill effects. Naturally being sympathetic and knowing of his own struggles to recover and the value of exercise while in bathing, he created at Warm Springs, Ga., a sanatorium where those

suffering from the disease may utilize the warm spring water to bathe in and under expert instruction learn to develop muscles which before they had believed to be useless. Of course only a certain amount of improvement is possible in bad cases.

Public Measures—In many cities one or more trained physicians have been appointed to go to children who are thought to be developing infantile paralysis and there to look for some or all of the following symptoms, headache, drowsiness, vomiting, diarrhea, fever, pain and stiffness in the back of the neck and spine, general hypesthesia and irritability. If a sufficient number of these symptoms are present, a spinal puncture is made and some spinal fluid removed. This is sent to the laboratory and if changes in the spinal fluid suggestive of this disease are noted and no paralysis has appeared, an injection of human convalescent or of refined anti-poliomyelitis horse serum is given. Careful statistics are being compiled in order that we may know whether the treatment does good on the first day, the second day or the third day of these symptoms. As I have already stated, we know that after the development of paralysis no benefit can be expected from the serum. The disease is so striking in its ill effects that we are more alarmed than the number of cases usually makes necessary. However, the disease is so tragic that we cannot blame parents for worrying.

THE RATIONALE OF WEIGHT REDUCTION

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THE weight reduction wave that threatened to reduce all our young women to "bean-pole" outlines a year or so ago has happily in part receded, yet even to-day the interest in weight reduction is so great that the lecturer on physiology, medicine or nutrition has but to introduce the words, "weight reduction" at any part of his discourse to change a quiet, sleepy group into an eager, agitated, expectant band of zealots, all on edge to secure any last-minute advice on the methods of losing flesh. To paraphrase a well-known text we may say, "Some people are born fat, some achieve fatness, and some have fatness thrust upon them." At the outset it is well for the body to be well nourished but not too fat. Babies are usually well nourished. One seldom hears of any effort to make babies thin, although after they begin to be fed artificially there may be over-feeding with an over-fat baby. In the period of youth and adolescence there is usually, especially with boys, such a tremendous amount of surplus energy and muscular activity that there is ordinarily no problem of weight reduction. With girls, too, in the grammar and high-school age little difficulty arises. One season I had occasion to wait at the front door of a large high school for girls, containing 700 pupils. Not five of those pouring out of the doors could have been charged up as being decidedly too fat.

But now, as to those that achieve fatness. The girl who gives up husky or tomboy activities for mid-Victorian repose and gentility begins to have trouble. She loves sweets; she loves delicacies and goodies just as before, but the exuberant activity of the early teens has by convention been repressed. The love for sweets has not been repressed and in goes the food and there is not the former outlet for the energy. Our patient now begins to acquire fatness and the fight begins. Frankly, until 35 years of age the question of overweight is a matter chiefly of fashion, for a little extra plumpness is from the standpoint

of health a real asset in the first three decades of life, since apparently it aids materially in helping to ward off the dread disease, tuberculosis. Now statistics perform some curious things, for apparently the night that you are thirty-five years of age the chances for a longer life are bettered if you are somewhat under rather than over weight, and it is between thirty-five and sixty years that the greatest danger appears and the struggle against the excess poundage is a real one. Why do people grow fat? There are, to be sure, a relatively small proportion of people with disordered glands who perhaps may be excepted, but in the vast proportion of cases there is just one answer; you eat each day a little more than you require. I repeat that you eat a little more than you require. If you eat the equivalent each day of an ounce of butter more than you need, what happens? You don't lose it; you don't burn it; it is digested, assimilated, and note this—it is deposited as fat. One extra ounce of fat means a pound in about two weeks or twenty-five pounds a year. All this from but one ounce, say three pats of butter, extra each day. Please note that I emphasize extra; that means three pats of butter above your daily needs. This goes on gradually, I might almost say insidiously, until the weight increases, the girth increases, the creases increase, and there you are.

All this is not sudden. You may not note it or you may wilfully disregard it. You may say, "Oh well, in the spring I'll get out and work it off." How will the bathroom scales help us in this matter? If you have bathroom scales use them at least once a week. If necessary write down your weight and watch the changes. Pay no attention to sudden changes either up or down. Let us see! What about sudden changes? Perhaps the most remarkable instance of a sudden change in weight that I ever knew of was that of a football player who on a warm fall afternoon lost 14 pounds during the afternoon and in this time he had played strenuous football for one hour. Now, thanks to careful analysis and studies in the physiological laboratory, it is perfectly possible to analyze this loss. Is it all body tissue? Is it fat? Is it water? What part of it is water and what part of it is fat, etc.? We know that when a football player plays to the limit of human endurance he can not produce more than say 600 or 700 calories of heat in one hour; in an extreme case 900 calories. Of course, during this time he is eating nothing, and this heat must come from material that is burned in the body and we will assume that it comes from fat. If this is all derived from fat it would require about 100 grams of fat to furnish these 900 calories. 100 grams of fat would be about 3½ ounces. As a matter of fact, he probably would not burn exclusively fat; he would burn a little carbohydrate and some protein, but we can make an extreme case and say that he might have burned all told 100 grams of fat and 50 grams of either protein or carbohydrate. This is an extreme illustration. This makes a total of 150 grams of dry body tissue burned, that is, about one third of a pound. Now dry body tissue is not peeled off the body either internally or externally as such; it is accompanied by water, and in this particular case we can see that if he burned only one third of a pound of dry body material and lost fourteen pounds there must have been thirteen and two thirds pounds of that loss due simply and solely to water. This was really a drying out of the body and it was probably all regained in the water and other liquids consumed, so that in one or two days at the outset the weight was essentially back to the original level. This furthermore illustrates the futility of trying to "work off" fat that has been deposited in the body. If it takes the terrific strain of one hour's football competition to work off or burn up one third of a pound of body tissue, what

chance has the untrained, soft non-athlete to work off any material amount? Work means heat. The heat is derived from food or from body substances, so that by working one does work off body substances, but as we have seen, in very small amounts.

To come back to our ounce of fat, let us make it rather than an ounce, a pat of butter, about one third of an ounce. This one third of an ounce yields a certain number of calories when burned in the body. Now if this one third of an ounce is taken in excess of the daily needs, only a little more, to work off that particular extra pat of butter taken on that particular day you would have to do work equivalent, for example, to a walk from the bottom to the top of the Washington Monument.

The best way of all to lose fat is not to get fat. If you are fat then it is nearly hopeless to attempt to "work it off." There is only one way to lose it intelligently, and that is to limit your daily food intake slightly and burn it up slowly, but remember that if we ate each day 3 pats or one ounce of butter less than we really needed, 25 pounds of fat would disappear in the course of a year. Of course, this could be done more rapidly, although with some danger, by complete fasting. In thirty-one days of complete fasting you could lose nearly 30 pounds, but again a good deal of this loss would still be water. It is impossible to lose weight and not lose some water, for the body is really 60 per cent. of water, but what you want to lose is the fat, and that is the main objective in weight reduction.

Bathroom scales are a very good index for the long pull, for reduction covering months, and you can not reduce except in terms of months. These fat zealots wish quick results, but think, those of you who are really overweight, how long you were putting on the extra poundage, usually several months if not years, so that you must take off that fat in a proportionately moderate way.

Reduction without the continual cooperation of a good physician may really be dangerous. Rapid results can not be expected. No overnight treatment is of value. Most of the innumerable proposals for weight reduction other than by intelligent diet control are not worth serious consideration.

Every extra calorie that you eat, be it from starches, sugars, fat or protein, must be looked upon as a potential fat producer. Fats are, so to speak, twice as concentrated as starches and sugars; hence if one avoids all visible fats in the food this is helpful. Cutting out visible fats is usually not a great hardship, but of itself is of value only when there is no compensation by overeating of other equally fat-producing materials. It is useless to cut out any particular article of the diet, such as bread or potatoes, and then fill up with ice cream. Diets of salads and greens which produce a feeling of fulness are sound in principle but may easily be overdone and produce digestive disturbances.

Exercise in moderation is, of course, essential to health. Extreme exercise, especially if one is not used to it, may be easily overdone, and then there is always this point to bear in mind—a ten-mile walk to "work off fat" usually is a wonderful stimulant to an appetite all too ready to be appeased.

The use of patent preparations to produce slimness, such as various chewing gums, is nonsense. While it is true that certain glandular extracts and drugs hasten the burning up of material in the body and thus contribute in a small way, at least, to reduction, they are without exception dangerous to use without the continued advice of a competent physician. There is no royal road to slimness. Diet reduction, at times demanding a Spartan-like abstinence from especially loved foods, is the only really logical procedure. It all boils down to a careful, intelligent curtailment of food or fuel intake. It might be termed "scientific stoking."

DENTAL CARIES AS VIEWED BY THE BACTERIOLOGIST

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DENTAL caries is without doubt one of the very ancient diseases to which mankind has fallen heir. True, we know little of the disorders which attacked soft tissues in primeval animal life, including man, since these structures nearly always disintegrated without fossilization. Our records concerning early infections are thus limited in nearly all instances to evidences of destruction within hard tissues, since it is these portions which have been preserved throughout the ages by nature's methods. Tooth decay was prevalent in prehistoric man, whether from northeast Africa, Asia Minor or Peru.

Dental caries is a process characterized by disintegration of the calcareous tissues of the tooth. These lime-bearing portions of the tooth may be listed as enamel, dentine and cementum. The enamel is that intensively resistant outer layer which covers all portions of the tooth exposed above the gum in man. It is by all means the hardest and most durable structure within the body of higher animals. The cementum is the outer layer of the tooth, of that region which usually lies below the gum line. It has certain of the characteristics of bone, and has for one of its main functions the furnishing of anchorage to the fibers which hold the tooth in position within its socket. Dentine lies inside the enamel and cementum and thus is adjacent to the pulp cavity.

Even though it appears wise to consider dental caries as an infection, one must guard closely lest such a statement be construed too broadly. Bacteriologists have rapidly been approaching the conclusion that disease is much more complex than merely the growth of bacteria within certain tissues of a host. Infection denotes a change in degree of activity of at least two different factors: first, there is to be considered the invasive power of the bacterial organism, and second, resistance on the part of the tissues concerned. According to our modern concepts of growth of bacteria, their virulence, which is really their invasive power, may vary. Reasons for these changes are understood very imperfectly at the present time. The ability to resist bacterial invasion on the part of the tissues of the host constitutes another variable. Infection thus results from the overturn of a balance between a potential invader on the one hand and tissues of changing resistance upon the other. At the same time then one must not ignore the fact that, no matter how weakened in resistance tissues may be, there can be no infection without the presence of an infecting agent. Unfortunately the infecting agent usually is close by in this world of ours, but these principles underlying infection doubtless hold in the consideration of dental caries just as they do in other examples of invasion by bacterial forms.

There are many theories of the cause of caries in the teeth, and when finally we understand what this disease really is, it is likely that we shall find that the etiology of this disintegration includes a combination of factors. These possible causes may be divided into two different categories, endogenous and exogenous. Each of these subdivisions has its own enthusiastic proponents. By endogenous

we mean that the cause comes from within the animal organism, while exogenous indicates the opposite, that is, that the cause is derived from without. An infectious agent thus must be included among exogenous causes. Among those factors which are inherent in the animal are to be included deficiencies in diet, and it is very certain that the teeth in their structure are most sensitive indicators of certain untoward conditions within the body. Extensive work has proved that lack of certain vitamines is reflected quickly and definitely by a certain picture of changes within tooth structure. It seems very probable, moreover, that such changes resulting from improper diet may be attended by increasing susceptibility to bacterial invasion. Doubtless the question of the relationship of diet to tooth structure is one of vast importance. There is a great demand for the element calcium within the animal body during childhood and also during pregnancy, for these are periods when bone and dental structures of the body are in process of formation. Calcium is necessary to the formation of these tissues particularly. It is not strange therefore that dental caries often appears intensively during these periods. The after effects of syphilis, especially in succeeding generations, may appear as certain malformations of the teeth when irregular and weakened dental structures may be formed, with the result that not only is the tooth less resistant to disease but its very shape makes invasion by bacteria relatively simple. These examples have been cited as factors which are endogenous in classification, and the list is by no means complete as given above.

The exogenous factors which may operate in dental caries are probably to be limited to the bacteria and the protozoa. As regards tooth destruction, the importance of the protozoa is most likely very minor, but to the bacteria a considerable amount of attention has been devoted. Among the bacteria there are two different groups which have been examined with care in so far as concerns their possible relationship to dental caries. These are a long, slender rod and a streptococcus, but it is very probable that the so-called streptococcus is only another form of the first mentioned rod. It has been recognized that this rod may appear in a number of different guises in culture and among these is the shape simulating a chain of small spheres so that it has been mistaken for a streptococcus. There is good reason for believing, therefore, that rod and streptococcus as found in the inner portions of disintegrating teeth, may upon occasion be one and the same organism.

If destruction of tooth structure is to take place as the result of the activity of certain forms of bacterial life, then these organisms must be endowed with certain qualifications. We have already noted the fact that the hardness of teeth is due to the calcium content. Organisms which can destroy tooth structure therefore must be able to break down calcium compounds. If they are able to produce acid in sufficient concentration, they may be enabled to do this. Acid usually but not always, when formed by bacteria, is derived by breaking down carbohydrate, and thus there is a definite relationship between carbohydrate and solution of calcium compounds as found in teeth.

Bacterial organisms which shall have the various requirements necessary in order to cause dissolution of dental calcareous structures have been given careful attention by a number of able investigators, including Miller, Kligler, Rodriguez and Bunting. All these have derived evidence to the end that there is a certain group of bacteria present in a carious tooth which are able to produce relatively high concentrations of acid and which also have the faculty of bring-

ing about disintegration of this resistant structure. In addition Mummery has shown by histologic technique that there are many bacteria present *in situ* in the cavity and that certain of these have penetrated into the dentine considerably in advance of the more evident area of disintegration.

The question of the incidence of acid-producing and of acid-resisting bacteria within dental caries offers a fascinating problem, therefore, and certain experiments dealing with this subject have been carried out at the University of California. No claim is to be advanced that much of the work is original in concept of thought. Part of it is confirmatory in character; another portion of it possibly may add a few items to the sum total of human knowledge regarding the subject.

Initial experiments were carried out, and for the able assistance of Mr. E. G. Ewer, who was associated with me in this particular endeavor, thanks are extended. With the cooperation of the university infirmary dental staff a careful attempt was made to isolate organisms from dental caries which should fulfil the qualifications necessary to break down the resistant framework of teeth. The work was done upon twenty-five different patients, nearly all of whom were university students. One cavity only from each mouth was examined. The technique utilized was as follows. The cavity in the tooth under test was first cut to its approximate size by means of the usual dental instruments. Tincture of iodine was then applied not only to the inside of the nearly prepared cavity but also to the outside of the tooth and to softer surfaces adjacent. Our previous work had proved that iodine is a most efficient germicide to sterilize the surfaces of oral tissues, and that it is effective in less than one minute for this purpose. After the iodine had been allowed to act for two or three minutes, the operation of preparing the dental cavity for filling was then continued, but now a freshly sterilized bur held with a sterile hand piece was used in order that the possibility of entrance of external contamination might be reduced to a minimum. The iodine-treated surface at the bottom of the cavity was cut away and then the hard particles which the burr subsequently cut from the underlying dental tissues and which were in turn lifted out while still sticking to the cutting instrument, were carefully transferred to medium. The medium thus inoculated was incubated at 37°. From twenty-four of the twenty-five explorations thus described we isolated rods which showed considerable variation both in morphology and in dimension. Usually they were long and slender but sometimes they appeared distinctly club shaped. Oftentimes they were granular when stained, and in a few instances they might have been mistaken for short chains of spheres on account of the distinct granulation which was revealed. Culturally, all presented difficulties when one attempted to grow them upon solid media as in Petri dishes, but one was impressed with the fact that all the twenty-four cultures derived belonged to the same general group.

The next endeavor logically should be to determine whether these organisms which had been isolated from carious processes were able to cause the deterioration of resistant dental structures. To this point attention was therefore devoted.

In preparation for these particular tests concerning the possible destruction of dental enamel and dentine by means of bacterial activity, it became advisable to determine the degree of hydrogen ion concentration necessary to bring about distintegration of dental tissue. For this purpose, therefore, a supply of human teeth was obtained. These had been extracted some time previously and

then after careful cleansing had been dried. There were no carious processes evident in any of them. These were first prepared by applying three or four coatings of shellac. When thoroughly dried in an incubator for a number of hours, the shellac covering was cut away from an area upon the crown approximating one eighth of an inch in diameter, in order to expose the tooth structure at that point. A series of solutions of hydrochloric acid of different hydrogen ion concentrations varying between pH 3.0 and 5.0 was set up. Into these solutions the teeth were inserted and then maintained at a consant temperature of 37° C. over the period of the experiment, which was twenty-three days. We replaced the acid solutions every two or three days in order to maintain a constant degree of acidity. The area exposed to the activity of the acid was limited as outlined above for a two-fold purpose. First, it was desired to obtain a single area upon the tooth which alone had been acted upon by the acid so that any final effects might be the more evident by contrast with the remainder of the tooth which had not been in contact with the acid. In the second place, neutralization of the acid by the calcareous material of the tooth would be much less if only a small area of the tooth were exposed to the acid and therefore likelihood of maintaining a constant concentration of the acid solutions throughout the period of experiment would be increased. To obviate this second possible difficulty the solutions were changed frequently as an added precaution.

At the close of this experiment, the teeth thus treated were removed from the several solutions, washed and the shellac removed by means of alcohol. Examination then disclosed the fact that evident dissolution of the tooth structure had followed exposure to a solution the acidity of which was pH 4.0 or greater. In other words, a hydrogen ion concentration of 3.0 to 4.0 was attended by destruction of the tooth, but if the potential were between 4.0 and 5.0, then little or no effects could be observed.

It thus becomes evident that if destruction of dental enamel and dentine is to be brought about, a certain concentration of hydrogen ion must be present.

Our next step in preparation for observing the effect of these cultures upon tooth structures was to determine the end point of concentration of acidity produced by these cultures in a certain standard medium, in relationship to the final degree of acidity in similar medium produced by strains of *B. acidophilus* derived from the intestine. There has been much discussion during recent years regarding this special point. Certain authors have maintained that these organisms from teeth, in their ability to produce acidity by breaking down carbohydrate, vary in no respect from those similar cultures isolated from intestinal contents. Others, on the contrary, hold that dental strains are more active than those from the lower digestive tract, and that thus they can and do produce a higher degree of acidity than the latter. In the course of our work it became necessary for us to give attention to this matter, and in preparation for this test six strains of *B. acidophilus* stated to have been isolated from intestinal material, were obtained from Dr. N. Kopeloff, of New York City.

As a medium for this experiment dealing with the relative concentration produced by these bacterial strains, we selected milk, since their growth in this is luxuriant. The same batch of medium was used for all cultures included. The various containers of the medium, after inoculation with the organisms, were incubated at 37°, and from time to time tests for purity were made both by stain and by streaking out on glucose agar. At the end of ten days, all these flasks of cultures were tested electrometrically

to determine the final pH of the solutions. All the twenty-four strains derived from dental caries gave readings lying between pH 3.3 and 3.7, while the six strains of intestinal origin yielded results between pH 3.7 and 4.3. Thus it was shown that dental strains of *B. acidophilus* are more intense producers of acid than those from the intestine. It becomes evident therefore that destruction of a tooth should be produced more readily by the first group than by the second.

In preparation for the actual test concerning the possible effect of *B. acidophilus* upon teeth, the technique followed when surveying the effect of acids upon teeth was utilized. There were certain additional precautions which, however, must be observed. The teeth under test must remain suspended in the culture and one must be able to transfer the tooth from tube to tube of culture medium. Some simple method of manipulation of the tooth thus must be provided. With this end in view we attached a fine thread to the apex of the tooth by means of shellac. The thread then in turn could be held between cotton plug and the lip of the culture tube so that now the dental tissue was suspended. Covering by shellac and subsequent careful abrasion of a small area upon the crown was carried out as outlined in our previous discussion. The teeth were then sterilized by steaming intermittently in the Arnold.

We then prepared cultures in milk of the thirty strains of organisms of which twenty-four had been cultured from teeth and six from fecal material. The human teeth prepared as outlined in the previous paragraph were then suspended within these cultures and again we maintained a constant temperature of 37°. It should be remembered that in the mouth there is constant flushing on account of the flow of saliva with the result that products of bacterial metabolism are removed. True, the effect is but momentary, since organisms are constantly flourishing and thus these products are rapidly replaced. We do know, however that there is a decided self-inhibition with consequent death curve if these products are allowed to accumulate in great degree. We obviated this difficulty in small part by transferring the teeth now under test to fresh and rapidly growing young cultures of the organisms once weekly. By so doing, younger and more rapidly proliferating bacterial organisms were utilized and a maximum effect upon the teeth was to be expected. Inasmuch as the teeth were suspended upon threads, transfer was a simple matter and possibility of contamination was reduced to the minimum. The experiment was prolonged for a period of six weeks, and at its conclusion the teeth were washed in water, dried and then examined to determine the nature of effects produced upon that surface of the tooth which had not been covered with the shellac and which therefore had been exposed to chemical action on the part of the bacteria.

Disintegration of the dental structures had been produced by each of the twenty-four cultures derived from dental caries, while on the other hand only one of the six fecal cultures of *B. acidophilus* had produced any visible effect whatever. Moreover, this artificial caries which had been induced was of additional interest because of the fact that not only had cavity formation progressed at the exposed area, but in addition, the chalky, white appearance which attends the advance of caries clinically was evident. Therefore, it was demonstrated that these organisms removed from teeth are able to bring about distintegration of tooth structures altho· the probability of like action on the part of fecal derived forms is vastly less. In this connection it will be recalled that the final pH of

cultures between these two origins of strains also differed.

There are certain points of interest regarding the metabolism of these bacterial forms which are of importance. They require carbohydrate for energy, and by the splitting of this, acid is produced. Nitrogen is essential. The question arises as to the source of food materials necessary for the life activities of these organisms. Attention is due the white material which readily accumulates in the interstices between teeth and upon their uneven or rough surfaces. It has been determined that this materies alba yields carbohydrate, nitrogen compounds and inorganic complexes necessary for growth of *B. acidophilus*, and that therefore there is a certain relationship between the presence of this white material which is in part incompletely digested food material and the growth of *B. acidophilus*. This particular point of itself weakens the arguments of those who reason that these bacteria can have no causative relationship to caries and who base their reasoning upon the statement that caries does not progress to any marked extent after death of the host. They say that the necessary organisms are present in the mouth of the dead host and yet the advance of caries now is arrested. The real explanation lies in the fact that no longer is there an intake of starch from which later simpler sugars are inverted. These and other food materials necessary to growth of the bacteria are lacking. Of necessity the progress of caries must be arrested after death of the host. The essential metabolism of the bacteria constitutes a limiting factor to their proliferation.

One may argue that bacteria are not the cause of caries since at times cavities appear upon surfaces of the tooth where seemingly it is smooth and thus in a location where bacteria can not accumulate, since these particular forms are unable to stick to a smooth surface. These arguments are answered in part by the possible presence of malformations upon the tooth and again by plaque formation due to precipitated mucin in an acid medium. In addition to these, however, there is another factor which lies within the field of the bacteriologist, for inside of the human mouth is to be found still another group of bacteria which may be of surpassing importance to the initiation of caries. These are long chains of rods which are cultured only with great difficulty over a sequence of culture-generations, as has been demonstrated by certain European workers. The members of this group, of which the organism Leptothrix is an example, tend to attach themselves tenaciously to surfaces and thus offer a site for growth to accompanying forms. On account of the anchorage afforded the Leptothrix and allied forms, cavities ultimately may be produced by organisms because of the opportunities offered by proliferation of a form entirely foreign to the final result. In all probability this is an example of commensal activity of bacteria within the human mouth.

While considering the general question of the growth of these forms of *B. acidophilus* in and upon teeth it is wise to direct our attention to the fact that dental caries means more than merely the solution of calcareous compounds within the tooth. In cooperation with Miss Williams in our department at Berkeley, it has been demonstrated that there is an organic framework in enamel. That there is such a structure in dentine has long been recognized. This dental enamel matrix, however, is extremely tenuous and difficult to reveal. Very fine determinations made by Evans years ago indicated that in human enamel there is a possibility of only 1 to 2 per cent. of organic matter. Recently the work of Bodecker and Gies in New York and of the author upon the Pacific Coast has proved not

only that there is a protein framework within dental enamel, but that it is definitely organized and with fairly exact morphology. In this particular field our work was done with the teeth of the guinea-pig, and it was demonstrated that the matrix found within the enamel consists of a honeycomb of tubes which are 1.5 to 2.5 microns in diameter. Within these the enamel rods are laid down. Additional details may be obtained by reference to the published work of the author. Dental caries, therefore, in addition to the destruction of calcium compounds includes solution of organic materials.

In cooperation with Miss Rose, of our university, lengthy experiments have been carried out in an endeavor to tabulate cultural and serological characteristics of the series of *B. acidophilus* cultures derived from dental caries. It must be admitted that the usual sugar reactions used by bacteriologists to classify organisms here are inadequate. We were unable to determine any constant set of sugar and other cultural changes which may characterize this group, and in this we note the same picture of events as has been recognized by other workers in this special field. Many of the sugar reactions are inconstant even with the same organism following repeated trials. Some certain carbohydrates may be acidified at one time but not at another even though all known precautions be taken.

We met similar difficulties in endeavoring to observe agglutination reactions of these forms, for we desired to learn whether they may fall within certain groups as indicated by agglutination technique. Two rabbits were immunized by repeated intravenous injection of each of the twenty-four strains of dental bacterial organisms, and these injections produced no unfavorable reactions upon the animals. The antigen was prepared by growing the bacteria in glucose broth which then was centrifugalized and the sediment used for injection purposes. From time to time the titer of the several animals was tested by trial bleeding from the ear vein, and when finally it appeared that as high a titer as possible had been reached, the animal was sacrificed by exsanguination. The resulting sera were stored at ice-box temperature until further use. For our final work in attempting to classify these forms in agglutination types, we thus had available two sera for each strain, since two different animals had been utilized for each. A few of our strains gave spontaneous agglutination, and this we did not succeed in obviating either by reducing the concentration of electrolyte, which in this instance was sodium chloride, or by use of a compound such as sodium oleate to alter surface tension. These two or three strains were of course agglutinated by their specific sera, but they flocculated likewise in all other liquids utilized and thus with these the test was valueless. Each of the remaining twenty-one strains agglutinated with each one of the two of its specific sera, but there was no constancy of reaction with the antisera prepared against the remaining members of the group. On many occasions cross agglutination appeared, it is true, when one serum was used with the entire group of cultures, but when the duplicate serum prepared for that particular strain likewise was placed against the whole series of antigens, there was no guarantee that the second serum would operate in a manner identical to that of the first. The sera therefore against strains which did not show spontaneous agglutination were always homologous, but they proved to be very irregular in heterologous relationships. Thus our efforts to prove type relationships within this group of *B. acidophilus* isolated from dental caries were fruit-

HUMAN TEETH
DISINTEGRATED LOCALLY BY *B. acidophilus*
ISOLATED FROM DENTAL CARIES.

less. We are of the opinion that these forms do not fall into type relationships in the accepted technical sense of the term.

The question of varying degrees of resistance to the infection of caries is a most baffling one. That this resistance to infection really does exist in many instances is certain. Moreover, it may vary in the same individual, since there are a number of instances on record where the advance of a carious process has stopped. The fact that in such arrested caries, strains of *B. acidophilus* may be isolated from the lesion which now no longer is progressive, has in turn been seized upon by those who oppose the idea that dental cavities result from bacterial activity. It should be recognized, however, that this objection to a possible etiological factor present in an inhibited site is not entirely valid inasmuch as similar conditions of arrest in the face of the presence of an infectious agent are found rather frequently in other portions of the body. It is very likely that in these instances and in cases of others who appear to be constantly resistant to the onset of dental caries there are factors at present unrecognized which operate towards prevention. It is conceivable that these may be chemical or physical; possibly they may even be anatomical in character. It is likely that the future will reveal some relationship now unknown between susceptibility to dental caries and diet.

The question of resistance to dental caries all too frequently is confused with immunity. By immunity one means an opposing factor either cellular or humoral or both which has resulted in the formation of antibodies through circulatory contact with an antigen. Such immunity presupposes a tissue and circulatory articulation which probably does not exist within dentine and which is still less likely possible in enamel. It is true that channels of intercommunication through the junction between dentine and enamel have been demonstrated

B. ACIDOPHILUS
ISOLATED FROM CARIOUS TOOTH. PURE CULTURE.

repeatedly by workers. Indeed in our collection of materials we have slides showing these. It is true also that the researches of Van Beust and others indicate channels of a sort within enamel itself. Nevertheless, the lumena of these passages is so small that one can not conceive that a cell of any sort may pass through them. Circulation if it exists at all can include at most merely the slow passage of an extremely small amount of fluid entirely without cell contact. Even this degree is by no means an assured fact. In light of these considerations, it seems very likely that there can be no immunity in the usually defined sense of this term of a host towards dental caries. Resistance has been demonstrated, but that is not immunity.

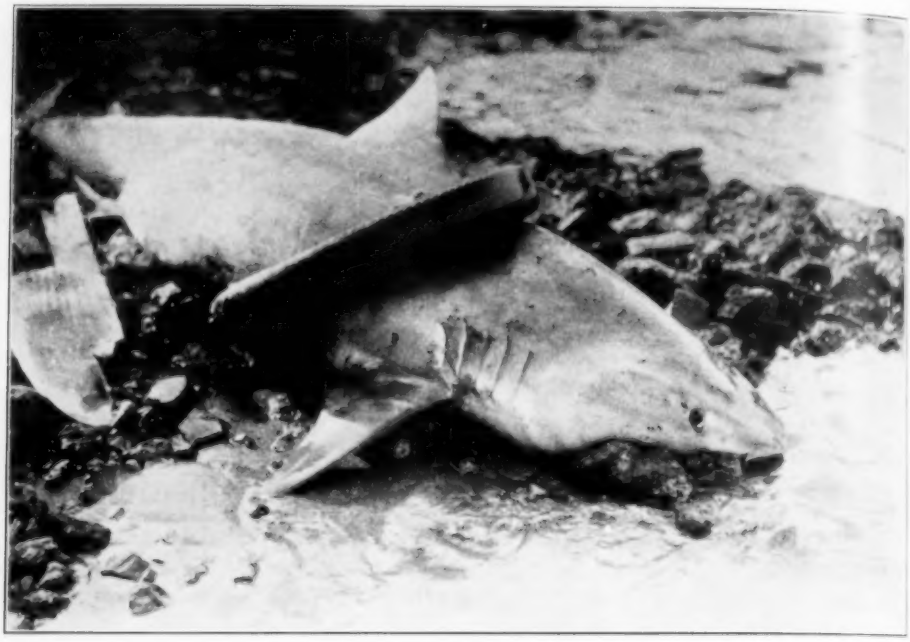
In this discussion, then, it has been our endeavor to show that it is probable that there is a bacterial etiological factor in dental caries. No claim is entered that this is the sole factor, but we have attempted to prove that organisms which may be cultivated nearly always from a carious lesion may in turn induce the result. A certain degree of hydrogen ion concentration is necessary in order to break down human teeth by solution. These organisms produce this appropriate degree of hydrogen potential. Likewise they can dissolve the calcareous structure of dead teeth. The metabolism of these forms is in large degree dependent upon decomposing food materials found about the teeth. In addition dental caries includes more than the mere solution of dental calcareous material since an organic matrix in enamel is liquefied also. These organisms are not identical in all respects to other groups found within the intestine since the final degree of acidity produced is not the same in the two series. A commensal relationship between two different groups of bacteria appears to function within the mouth since one series may furnish anchorage for another.

These caries-inducing bacteria do not show constant cultural reactions particularly as regards their effects when in contact with certain carbohydrates. Neither do they show immunological types. The probabilities of true immunity in dental caries seem to be remote.

A SHARK ENCIRCLED WITH A RUBBER AUTOMOBILE TIRE

By Dr. E. W. GUDGER
AMERICAN MUSEUM OF NATURAL HISTORY
and Dr. W. H. HOFFMANN
LABORATORIO FINLAY, HABANA, CUBA

THE senior author has already published two articles (*American Museum Novitates*, 1928, No. 310; and *Annals and Magazine of Natural History*, 1929, ser. 10, vol. 4) describing mackerel and other fishes with rubber bands encircling and even partly imbedded in their bodies, and has on hand six other specimens showing this phenomenon in more exaggerated form. What then could be more logical than for the junior author to send him a clipping from the rotogravure section of the *Diario de la Marina*, of Habana, Cuba, for Sunday, September 21 last, containing a reproduction of the picture which is included in this article. Above the picture was a short caption and below an interesting account of the phenomenon. A translation follows herewith.



—Photograph by courtesy of *Diario de la Marina*, Habana.

THE SHARK, ENCIRCLED BY A RUBBER AUTOMOBILE TIRE, ON THE SHORE OF COJIMAR BAY, EAST OF HABANA HARBOR.

THE LAST CONTRIBUTION OF A RUBBER TIRE

In the vicinity of the coast opposite Habana, where fishermen are navigating their small boats daily, two fishermen, when outward bound as usual, recently saw an enormous shark which was making a great disturbance at the surface of the water. It was unable to swim and apparently remained stationary as if moored by an anchor at the bottom of the sea. The fishermen, actuated by curiosity and the desire to make a good catch, decided to approach the fish. When they did so they were surprised to see that it was a shark of the "Alekrin" kind about five meters long which had been caught by a rubber tire . . . which the owner had thrown into the sea, having decided to replace it by another.

This shark, one of the most voracious of its kind, seeing the circle of the rubber tire, had thrust its head into its center and there remained trapped in the manner in which we see it in the photograph. This placed it in a position to be easily captured thanks to the rubber tire. This latter, after having for many years rendered its service to an automobile, nevertheless cheers us with a last contribution—the deliverance from one of these terrible sharks.

A letter to the director of the *Diario de la Marina* brought a copy of the photograph and a very courteous reply from Señor Gonzalo Menéndez, the managing editor, expressing his regrets that he could give us no further information than that contained in the note above set out. Inspection of the figure showed the shark in question to be a male of a non-determinable species.

Information has been hard to obtain, but the persistence of the junior author has finally produced some data. Our first efforts were to ascertain if the fish swam into the tire or if it was caught and the tire put on it by human hands. Our earliest information was that the fish when seen by the fishermen as noted above was literally "alive and kicking" but unable to move save at a snail's pace. It was in the bay of Cojimar, off

a small fishing village about five miles to the east of the mouth of Habana Harbor—from which place we have recently put on record the capture of a second whale shark from Habana waters.

Our next information came from a gentleman who saw the fish alive but who described it as very weak, almost dead. This exhaustion was undoubtedly in part due to the efforts it had made to swim in spite of this great hindrance, and in even greater degree because it had practically been unable to catch any food since it became encumbered with this tire.

Finally Dr. Hoffmann himself made a trip to Cojimar and there found the fisherman who gave us our most reliable information about the second whale shark. He also saw and talked with the two boys who actually caught the shark. All three of them saw the fish swimming along and trying to jump out of the water in its efforts to free itself of the incumbrance. But these only drove the tire further back until it had come to encircle the body of the shark just in front of the first dorsal fin. One man said that the tire was so tight on the fish that one could see the ring it had made in the skin and flesh, and that the only way to get the tire off was to cut the shark to pieces—as was done. This, if correct, would indicate that the tire had been on the fish for some time.

The shark was actually caught by two boys who cautiously approached it as it was floundering along on the surface of Cojimar Bay. When they saw that it was practically helpless they approached nearer and getting a lasso over its head brought it to shore where they killed it after it had been photographed.

Now the final question is how did the tire come to encircle the shark as is shown in the photograph? And at once we may dismiss the idea that it was placed there by the hand of man. No sane man is going to attempt to put an automobile casing over the head of a large vigorous savage shark and to drive it back clear of the pectoral fins. We believe that the explanation is to be found in the following facts, which agree in essence with those offered by Dr. Gudger to explain how his specimens of northern fishes came to be adorned with rubber bands.

As in New York, so in Habana, garbage, street cleanings, wastes of all kinds are collected, loaded on scows or barges, and these are towed out to sea and their loads dumped overboard. Sharks are scavengers and they attend these scows to their unloading grounds to feed on garbage. When this with the worn automobile tire and other like débris was dumped overboard, our shark dashed into it to pick up what he could to ease his hunger. The open ring of the automobile tire confronted him with something edible beyond. Laying his pectoral fins close against his sides, he drove through to find himself stopped when his non-bendable dorsal fin struck the rim. Finding himself caught he became panic-stricken and pushed against obstacles to sweep this clinging thing free from his body—with the results that we have seen.

THE BANTING GROUP

One species of ovis is probably the progenitor of domestic cattle

THE PROGRESS OF SCIENCE

THE VERNAY-FAUNTHORPE HALL OF SOUTH ASIATIC MAMMALS

THE American Museum has opened the new hall of South Asiatic mammals dedicated to the men whose efforts had brought it into being, Arthur Stannard Vernay and the late Lieutenant-Colonel John Champion Faunthorpe. It is believed that this is the first occasion that an entire museum hall, filled with large groups of the major species of mammals especially mounted for the hall, has been opened to the public as a completed entity. That such a comprehensive collection of South Asiatic mammals could be assembled, mounted and displayed in harmony with the ideals of best modern practise in the comparatively brief span of years from 1922–30 is due to the enthusiasm and energetic support of the two Englishmen for whom the hall is named.

In 1918 Lieutenant-Colonel Faunthorpe, then a member of the British War Mission to the United States, visited the American Museum and at a conference with President Henry Fairfield Osborn suggested that he undertake to secure in the field some of the species of large Asiatic mammals so conspicuously absent from the museum halls. The suggestion appealed to the president of the museum, the idea was expanded when Mr. Vernay joined Colonel Faunthorpe in volunteering his services in the field and the plan for an entire hall of mammals collected by these gentlemen took concrete shape.

Messrs. Vernay and Faunthorpe were familiar with local conditions in southern Asia, they had the entrée to those entrusted with the care and preservation of large game and were altogether well equipped by experience and training for the task they had undertaken. Most important of all was the generous assumption by Mr. Vernay of all the necessary travel and field expenses and, in addition to those, some of the costs of mounting the material after it reached the museum.

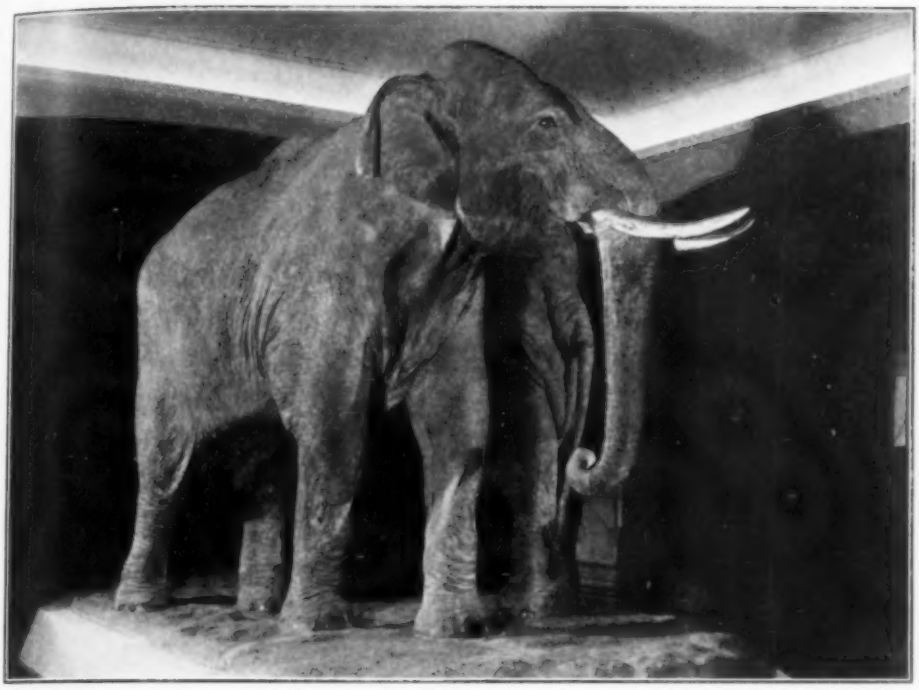
The first expedition was launched late in 1922 and was followed by no less than five others before all the material needed had been secured. No efforts were spared to obtain the finest possible representation of the important mammals of southern Asia and on one of the expeditions Mr. Vernay took with him Mr. Albert S. Butler, assistant chief of the museum department of preparation, to collect accessory materials, and Mr. Clarence C. Rosenkranz to paint background studies.

Messrs. Vernay and Faunthorpe met everywhere with the cooperation of the various Indian princes and government officials without whose sympathy the enterprise could not have achieved such success. It was a great tragedy that Colonel Faunthorpe should be stricken with pneumonia while in Lucknow, in 1929, and did not live to see the final and tangible expression of his dream of an Indian hall.

The Vernay-Faunthorpe Hall displays the outstanding species of the larger mammals of southern Asia and by means of painted backgrounds and skilfully arranged accessory material creates the illusion in the mind of the beholder that he is looking upon a transported bit of Asia. Mr. James L. Clark, assistant director in charge of preparation, has been extremely successful in creating a convincing, harmonious and artistic display of wild life. The architecture of the hall is simple, but carefully designed, with the motif of the older Indian culture worked out in teak wherever wood is used. The lighting of the groups is all from within, each group an individual problem, and there are no disturbing reflections as is the

SAMBAR AND SWAMP DEER GROUP

REPRESENTED IN A MARSHY TRACT IN THE TARAI, ALONG THE FOOTHILLS OF THE HIMALAYAS.



THE INDIAN ELEPHANT GROUP

case with external lights. The exclusion of direct sunlight prevents the rapid fading of pelage. There is ample illumination where it is needed and yet the average light intensity is so low that the eye experiences a distinct relief and relaxation when the visitor enters, and "museum fatigue" is left at the threshold.

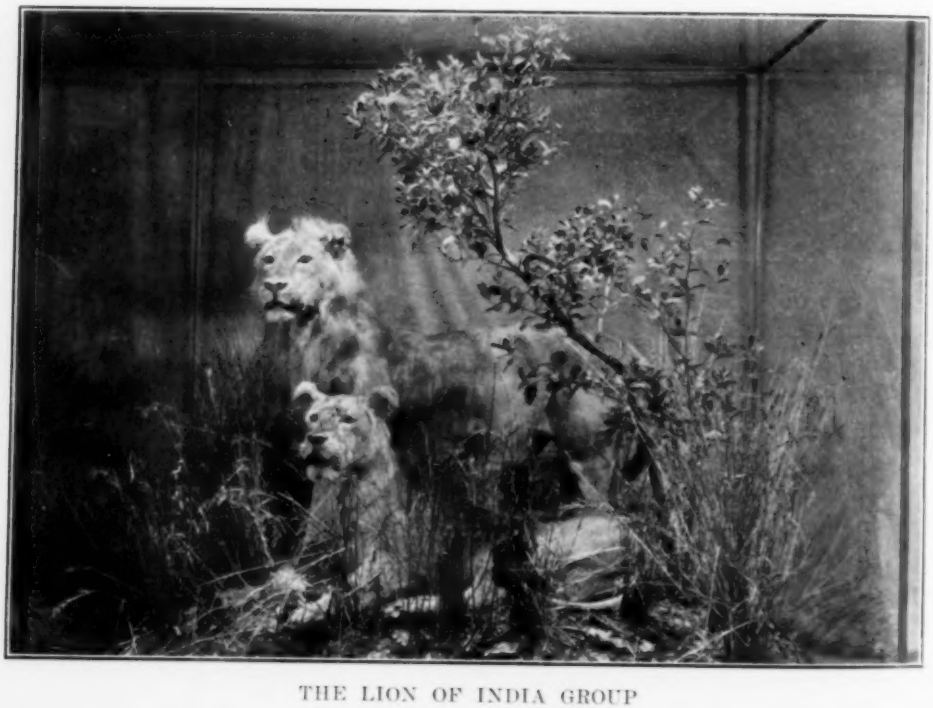
There are eight large habitat groups in the hall, displaying respectively the Indian rhinoceros, banting, Sambar and swamp deer, tiger, leopard, Sambar stag and wild dog, gaur and Indian buffalo. Smaller habitat groups present Eld's deer, Hoolock gibbon, black buck and Indian gazelle, and axis deer. Open groups down the center of the hall show a pair of Indian elephants, a pair of the very rare Indian lions, the sloth bear, and the nilgai. Lesser species from wild boar to mouse deer are contained in cases placed in lateral alcoves, where a female and young of the scarce Sumatran rhinoceros keep them company.

It is difficult in words to set forth the convincing elements of illusion so apparent upon a visit to the hall. Hunters of Indian game recognize the exact spot where the Himalayan foothills overlook the swamp deer, for example, the reason being that the background is a faithful painting of a specific locality and not just a pleasing pigment of the artistic imagination. The mammals appear to be capable of movement in the next instant, and in many similar details Mr. Clark and his staff have achieved an unqualified success.

Mr. Vernay and Colonel Faunthorpe wished to express through the donation of this matchless collection of mammals some of the great friendship and affection they felt for America, and the American public is greatly indebted to these sportsmen for this privilege of having always on display such a comprehensive assembly of the fast disappearing mammals of Southern Asia.

H. E. ANTHONY

THE LEOPARD GROUP



THE LION OF INDIA GROUP

THE NEW REFLECTOR TELESCOPE OF THE U. S. NAVAL OBSERVATORY

MANY years ago I overheard a famous old admiral say to a younger officer: "Don't tell me what you are going to do. Wait till next year, and tell me what you have done." A fine working principle for sailor-men; but it doesn't suit the press, which is continually striving to get advance information of what is going to be done. And so it is in this case of our big new reflector telescope.

Frankly, I would much rather wait till the work is finished, and the results would speak for themselves than to go counter-clockwise to a habit of years, but a telegraphic request for a description of our new telescope can not be delayed a year without discourtesy. It is with extreme reluctance, however, that this task is undertaken.

Our contract calls for the construction and installation of a Ritchey-Chrétien Aplanatic 40-inch Reflecting Telescope, complete with all fittings, driving mechanisms, refinements, accessories, etc. The contract price is $76,000, and the time of delivery is to be within twenty-seven months. It is hoped that this date will be anticipated by several months.

The telescope will be mounted in a separate structure, which, in some respects, will be as wide a divergence from the usual type of observatory dome as the telescope itself is from the usual type telescope. Due to some unique features of the reflector, the size of the dome will be very much reduced with the consequent reduction in cost of the structure.

The telescope will measure not more than 10 feet overall, and the principal mirror will have an outside diameter of approximately $40\frac{3}{4}$ inches, with a clear aperture of 40 inches. Both mirrors will be made of a special grade, low-expansion glass having a coefficient of expansion only about half that at present in use. Professor Ritchey has been experimenting in the development of this glass for the past seven years in the famous St. Gobain glass works near Paris. Thanks to the liberality of that company, Professor Ritchey was permitted unlimited scope in his experiments in high-grade glass-making. As a result, he developed high-grade, low-expansion glass of a quality particularly adapted for reflector telescopes. This feat alone, if for no other, places Professor Ritchey in a premier position.

The principal mirror will be approximately 6 inches thick, and the secondary mirror will be approximately $2\frac{3}{4}$ inches thick. The latter will have a clear aperture of approximately 16 inches. The distance between mirrors will be approximately 96 inches and the equivalent focal length 271 inches.

The reflector will be mounted upon a large rigid iron casting, which in turn will be mounted upon a massive concrete pier. The bearings of polar axis will be supported on columns in the usual approved way. The entire weight of the telescope and all its auxiliaries will be taken up by a thrust bearing of Professor Ritchey's own design. This thrust bearing absorbs the load so neatly that the driving mechanism can turn the reflector with the greatest conceivable precision and smoothness.

The mounting of the telescope will permit observations clear to the celestial pole, and will be free from those annoying inconveniences which are sometimes present in equatorial mountings.

Professor Ritchey and Professor Chrétien have been perfecting the numerous accessories and developing the many refinements—some can truly be called super-refinements—since 1910, and have gradually brought their telescope to a very high state of perfection.

It is assumed that all the readers of THE SCIENTIFIC MONTHLY are more or less familiar with the fundamental prin-

ciples of this super-telescope; a really remarkable telescope, embodying as it does so many minute refinements and practical solutions of difficult problems.

Professor Chrétien proved by mathematical investigation that in order to obtain the finest possible results it would be necessary to restrict the investigation to a single equivalent focal ratio for a given telescope. He accomplished that by using a single pair of mirrors always in combination, a large concave and a small convex. The curves of these two mirrors differed slightly from the paraboloid and the hyperboloid, respectively, of the Cassegrainian system.

Professors Ritchey and Chrétien developed their formula for the curvature of their mirrors, which renders the combination so far superior to all others previously made, and as a result of which the Ritchey-Chrétien reflector is capable of such astounding results.

Having settled that very important question, they devoted their energies to the solving of the many problems, hoping to overcome the well-known difficulties in the various large reflectors.

Their success far exceeded their fondest expectations.

They have developed a very short, rigid, modified Cassegrainian type reflector with entirely new curves in their mirrors, giving them an equivalent focal length which permits the photography of very faint nebulae.

All questions of construction have received the closest attention and have been solved in very practical ways. No detail was too small to be thoroughly analyzed and solved, sometimes in a very ingenious manner.

The result is a reflector of extremely short overall length, stiff and very rigid, free from flexures, capable of very rapid and skilful work, and equipped with every conceivable refinement and convenience for the operator. As an example of the detailed study of each factor influencing the perfection of the result, Professor Ritchey has even gone to the refinement of manufacturing his own photographic plates. These plates will be round and approximately 7½ inches in diameter. They will be ground and polished by Professor Ritchey personally and their surface will be true to within one fifty thousandth of an inch. Professor Ritchey was not satisfied with the plates ordinarily used for astronomical photographs, nor was he satisfied with the emulsion. He therefore delved into the technique of photographic emulsions and developed one whose granulation is twelve times finer than that used at present. This special emulsion of Professor Ritchey's will be only 10 per cent. as thick as the usual emulsion on photographic plates. This will overcome the present comparatively uneven surface of plates used for celestial photography. By means of these special plates the rays from the celestial bodies will be brought to an absolutely accurate focus over the entire plate, a feat impossible with the present equipment in common use.

Unfortunately, many of the solutions of the various problems represent in themselves what might be called "trade secrets." And as Professors Ritchey and Chrétien have not protected themselves by patenting these numerous valuable accessories and developments, it would be highly unethical for me to describe them in this article. Suffice it to say that they have developed some of the neatest and most ingenious refinements and accessories that can be imagined.

Professor Ritchey and Professor Chrétien claim for their reflector the following advantages: (1) Adaptability for the broadest general usefulness in astronomical photography; (2) arrangement of mirrors to permit the most convenient form of equatorial telescope; (3) focus of optical combinations in readily accessible position near the cen-

ter of motion of the instrument; (4) position of this focus never far above the floor level of the dome; (5) freedom from flexures of the tube; (6) reduction of the effects of expansion and contraction of the tube at least one hundred times; (7) permanence of alignment and the separation of the two mirrors; (8) ability to focus to one ten thousandth of an inch, in marked contrast to the present methods, which permit accurate focusing to only about one one-hundredth of an inch.

In addition to the foregoing, and as a result of some of those characteristics, Professor Ritchey called my attention to the large field of extremely small, round, concentrated images quite in contrast to the many others not possessing the same degree of definition or accuracy, particularly away from the center of the plate. The smallness and the clearness of images, even out to the periphery of the photographs, is very remarkable. A greatly increased accuracy of measurements of astronomical photographs naturally results.

In discussing the capabilities of the new reflector one day, Professor Ritchey remarked: "We shall make photographs with it which correspond to 90 per cent. of the full theoretical photographic resolving power due to the aperture, instead of the 10 per cent. or less represented by the best celestial photographs at present. And we shall do this where, of all places, it should be done: at our National Observatory in Washington."

The aim of Professor Ritchey was to develop a type of reflector of universal usefulness, one of great optical power and refinement but with great economy and convenience of all mechanical features.

Professors Ritchey and Chrétien will receive the thanks of the scientific world when the results of their years of painstaking investigation and development can be made public.

FREDERICK HELLWEG

MARTINUS WILLEM BEIJERINCK[1]

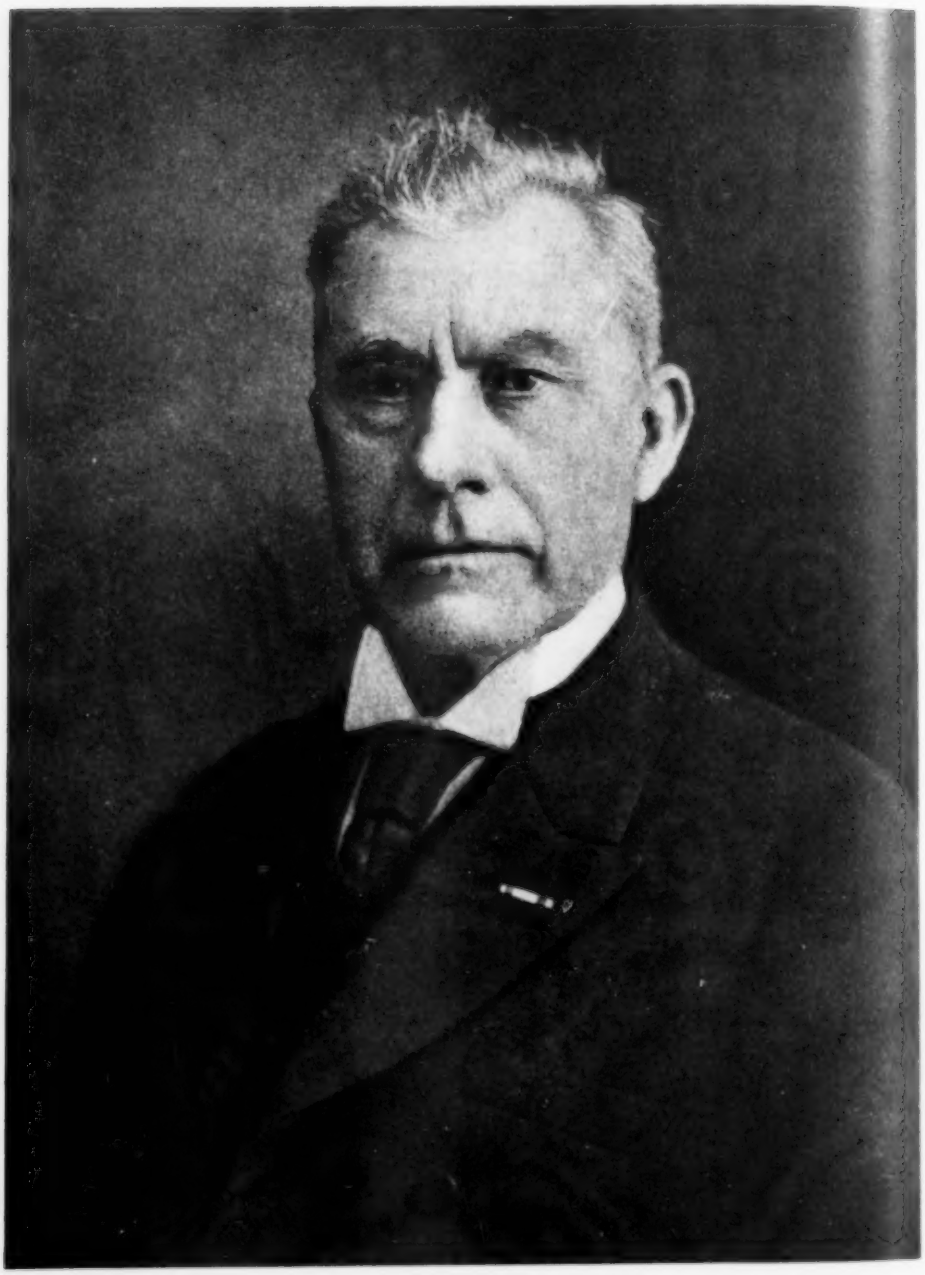
1851–1931

FAR from the great city and from his laboratory, there passed away on January 1, in a little town in Holland, one of the greatest scientists of the age, Professor Martinus Willem Beijerinck. Born at a time when Pasteur fought his great battle for the recognition of microorganisms as the active agents in disease, Beijerinck has materially contributed to our understanding of the rôle of microorganisms in natural processes and has indicated numerous applications of the activities of these microscopic forms of life to agriculture and industry.

When a youth, he used to wander over the sand dunes of Holland, in the neighborhood of Haarlem, and observe the life of these dunes. At the age of 16, he competed for a botanical prize, which consisted in making a collection of 150 different plants, and he won this prize. From this humble beginning, he proceeded to make some of the greatest contributions to our knowledge of microbes, including fungi, yeast, bacteria, algae and amoebae, as well as filterable viruses, and established their rôle in the growth of plants (pathogenic and beneficial), in soil processes and in industrial applications.

A friend of van't Hoff and of Hugo de Vries, he combined chemistry and botany to establish the rôle of microscopic forms of life as chemical reagents and thus advance further and enlarge greatly upon the ideas of Pasteur in the same field. Although his investigations did not lead to such spectacular results as those of Pasteur, those that have had an opportunity to familiarize themselves

[1] Journal Series paper of the New Jersey Agricultural Experiment Station, department of soil chemistry and bacteriology.



PROFESSOR M. W. BEIJERINCK AT THE AGE OF SEVENTY

with them will not doubt that he has opened as many new fields and has advanced our knowledge considerably in all of them. It is sufficient to mention his studies on the formation and genesis of buds and roots, as well as the general problem of regeneration in the field of plant anatomy; his studies on the phenomena of the plant-root galls and tobacco mosaic in the field of plant pathology; his discovery of legume bacteria, of the non-symbiotic nitrogen-fixing Azotobacter, of sulfur-oxidizing and sulfate-reducing bacteria, of nitrate-reducing bacteria and numerous others, in the field of soil microbiology and plant nutrition; his studies on the butyl-alcohol forming and butyric acid bacteria, the lactic and acetic acid bacteria, and the microbes concerned in the retting of flax, in the field of industrial microbiology; his studies on the nutrition of algae, amoebae and microbes in the field of general microbiology—to recognize the far-reaching and extensive contributions of this scientist.

Beijerinck was the pioneer to open up new fields for others to exploit and to follow. He had a keen mind and a great ability for observation. His methods of experimentation were always simple. He always devised new and very effective methods of investigation. The writer well recalls a visit to Beijerinck in the summer of 1924. Beijerinck was then already living in retirement for a period of three years, but was still able to prepare, by means of a few simple pieces of apparatus that one can devise in a country home, several experiments with Azotobacter and a few other bacteria, so as to have something to discuss.

PROFESSOR BEIJERINCK
IN HIS GARDEN (AUGUST, 1924)

PHOTOGRAPH TAKEN IN PROFESSOR BEIJERINCK'S GARDEN, AUGUST, 1924

In 1921, Beijerinck's numerous pupils, friends and admirers combined to celebrate his seventieth anniversary, and published on this occasion all his contributions to science in five volumes, which stand as a monument to his accomplishments. He was elected as honorary member by numerous foreign scientific institutions, as a sign of their homage to his genius.

Beijerinck had a very sensitive nature

and one had to come in very close touch with him to recognize how faithful a friend he could be. His personal life was very retiring. Never married, he lived for many years with his unmarried sisters, to whom he was very much attached.

A personal observation may well illustrate this point. This occurred on the occasion of the author's visit to Beijerinck's home, near Gorssel, in 1924. A very delightful morning was spent in discussing various problems in the field of microbiology, as well as Beijerinck's own impressions of Pasteur and other investigators in this field. This was followed by lunch, in which Beijerinck's only surviving sister and the writer's wife participated. The professor himself was rather somber, but his sister, who has evidently learned her English by reading Elizabethan writers, and not only scientific literature, enlivened the conversation considerably with various stories of their former and present life. Lunch finished, and the weather being rather pleasant, the group retired to the garden, where Beijerinck was still carrying on some experiments on plant breeding. The writer then begged permission to use for one moment his camera, so as to carry away a souvenir of this memorable visit. Beijerinck, however, declined very decidedly to pose or to even allow a rapid snapshot to be taken. "It is something I never allow to do," he stated in a tone that permitted no further discussion of this subject. However, a memento was to be taken at any price, so the writer proceeded to photograph the famous garden, to which of course the professor could see no objection. Miss Beijerinck, watching these proceedings with seeming amusement, willingly agreed, at the invitation of the amateur photographer, to pose in the garden. She immediately invited the other two ladies of the party, one of whom was the housekeeper, to join in this photograph. After the ladies were all ready and the camera was about to click, Miss Beijerinck turned to her brother, who was watching the proceedings from the doorsteps, and said: "You see, we are all going to be in the picture, and you are the only one not in it; perhaps you would better join us." He could not decline this invitation, and after covering his head with a cap he joined the group. After the group photograph, no further objection was raised to an individual one.

Although he officially left his laboratories about ten years ago, Beijerinck could not bring himself to give up active investigation altogether. His old love for botany was now revived, and in June, 1927, he submitted a communication to the Royal Academy "On the Position of the Leaves," a subject treated by him forty years previously, namely, in 1886. He also attempted to correlate certain phenomena in bacteriology, such as "chemo-synthesis" with "denitrification," and to deduce from these a general law of bacterial development. However, he was primarily a keen observer, who could deduce from his simple experiments important facts.

As is the case with many men of genius, once he postulated a theory, it was difficult for him to give it up, even in the face of accumulating contrary evidence. This was the case of the mechanism of fixation of nitrogen by leguminous plants. "What is your opinion?" he asked the writer. "Does the plant or the bacterium fix the nitrogen?" The writer was rather astonished, having felt all the time that the rôle of the bacterium in this process was recognized as definitely established. "Not at all," continued Beijerinck, "and it will be left for you younger workers in America, who are free from the prejudices that we are enveloped in here, in Europe, to take up the problem again and settle it definitely."

As one of the greatest microbiologists that ever lived, his loss will be felt throughout the civilized world.

SELMAN A. WAKSMAN